ENT SENIOR DESIGN PROJECT REPORT

Hydroponic Control System

Submitted to:
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Hydroponic Control System

ABSTRACT

The goal of this project is to design and construct a hydroponic control system. The control system will process signals from the required inputs and control output devices based on operational criteria. The control system will display the amounts of water and nutrients that need to be added on a daily basis to maintain a proper growing environment. A daily chemical test is required so these readings can be obtained. The desired nutritional specs are provided by Emerald Harvest Nutrient Series Feeding Chart. The system consist of 3 chemicals, Grow, Bloom, and Micro. The ratios of these 3 chemicals change on a weekly basis during the 16 week grow cycle. The system will continuously monitor the humidity of the grow area and cycle a humidifier to maintain the area within certain specs. Since the system is designed to be indoors, a way to control temperature is not needed. The grow lights are designed to supplement natural light and therefore the system needed to be placed near a south facing window. With minimal user interaction, the system should be able to provide adequate grow environment for up to 5 small herbs over an entire grow cycle. After a grow cycle is complete, the system is ready to start all over again.

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REVISION HISTORY

Date	Initials	Version	Update Notes
2017.04.06	ARM	0.01	Initial Draft Version
2017.04.16	ARM	0.02	Added System setup and System Operation
2017.04.23	ARM	0.03	Updated humidifier specs
2017.05.15	ARM	0.04	Updated power supply schematic and layout
2017.06.24	ARM	0.05	Added User interface and Interface sections
2017.7.21	ARM	0.06	Added sections for final review
2017.08.05	ARM	1.00	Initial Release Version

IUPUI Information

This project was completed by Andrew McNeely as a Senior Design Capstone Project. The Capstone Project is a requirement to obtain a Bachelor's of Science in Electrical Engineering Technology through the Indiana University-Purdue University of Indianapolis.

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1. INTRODUCTION

1.1 Problem Statement

Due to the climate of central Indiana, I am unable to grow fresh vegetables and herbs year round. Using my knowledge gained in the field of electrical engineering technology, I am designing a control system for a hydroponic system that enables me to grow fresh herbs inside my house all year long. If this control system is shown to adequately control the grow environment of herbs, I have the ability to scale up the operation to include larger vegetables.

1.2 Key Terms

- Hydroponics – The process of growing plants in a non-soil based media. Sand, gravel, or water can be utilized as a median along with added nutrients.
- Nutrient film technique (NFT) – A hydroponic grow technique that places the roots of growing plants directly in a slow moving stream of nutrient rich water.
- Potential of hydrogen (pH) – A scale to specify the acidity or basicity of a liquid solution.
- Total dissolved solids (TDS) – A measure of the amount of inorganic and organic particles in water.

1.3 System Overview

The technique used for this hydroponics system is a nutrient film technique. This type of system utilizes a reservoir to hold the excess nutrient rich water. This water is pumped through a trough and gravity drains back into the reservoir. The growing plants sit in the trough and the roots grow down into the water to receive the desired nutrients. The nutrient level of the water changes on a weekly basis based on which week of the grow cycle the system is in. The user actions to maintain the system include daily chemical test, addition of chemicals as displayed on screen, and maintaining water level of the reservoir.

Hydroponic Control System

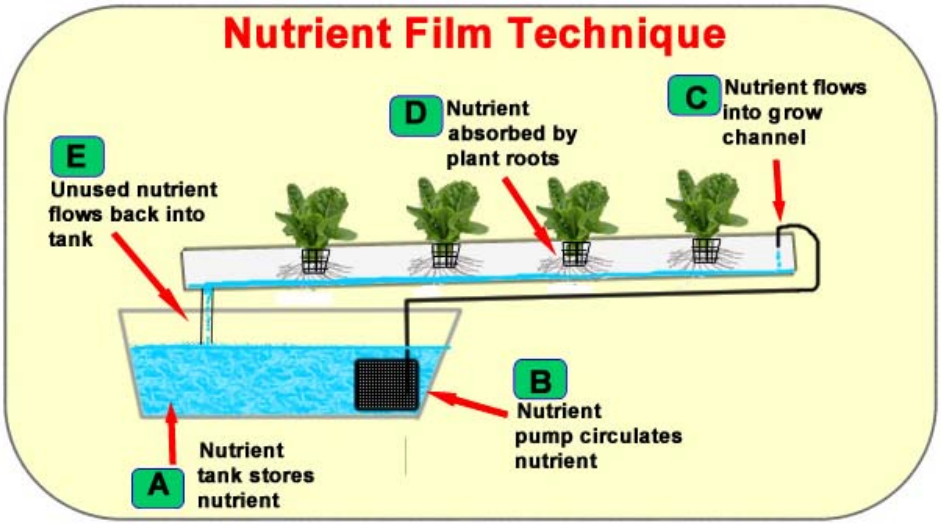

Figure 1 - Nutrient Film Technique

2. REFERENCED DOCUMENTS

Table 1: Reference Documents

Title	Document Reference Number	Appendix
Arduino Mega 2560	A000047	B
AMOTEC LCD Module Specifications	ADM1602K-NSW-FBS	C
LM2678 Simple Switcher Specifications	lm2678	D
AOSONG Temperature and humidity Module	AM2301	E
Ultrasonic Ranging Module HC-SR04	HCSR04	F
Uxcell Hall Effect Water Flow Sensor	Uxcell-Hall Effect Water Flow Sensor	G
SEN0161 pH Meter	SEN0161	H
DFR0300 Analog EC meter	DFR0300	I
Ultrasonic Humidifier Use & Care Manual	A1HllCAzl1L	J
ActiveAQUA Instruction Manual	aapw400	K
Emerald Harvest 3 part nutrient series	Feeding-Chart-GMB-3-Part	L

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3. SYSTEM-WIDE DESIGN

3.1 Design Trade Offs

- The most significant design criterion for this project is the overall price of the final design. The project is personally funded therefore the price of each component within the project had to be minimized while still meeting functional specs. Goal for a finished product was to not exceed $500.
- The system was designed to be placed in front of a standard window and have the ability to be moved from room to room as needed. This criterion limited the overall size of the frame to be no wider that two feet. The system can easily be broken down into 2 pieces, frame/controls and reservoir, for mobility.
- The system was designed to assist the natural sunlight with grow lights. This allows for smaller grow lights to be implemented into the system.
- I chose to use a standard 5 gallon bucket as the water reservoir. This meet both price and mobility criteria above. Due to the height of the reservoir, I needed the grow trough to be a minimum of 15 inches at its lowest point.
- An Arduino Mega control board was used due to the price and abundant I/O. The system required more I/O than an Arduino Uno could manage.
- The circulation pump decision was based on the overall pump height requirement of 15 inches. The pump had to provide enough flow through the tubing to a height of 15 inches.
- Each output of the system (humidifier, circulation pump, mix pump, and grow lights) had to draw less than 5 amps during normal operation. This is due to the relays used to cycle power to the devices.
- A humidifier had to have an on/off switch and not controlled by a microprocessor. I was unable to find one to meet this requirement and the ampacity draw from above so I had to modify the circuitry to make one meet this requirement.

3.2 Hardware

Each of the three printed circuit boards (excluding the Arduino Mega) were fully designed, tested, and implemented as part of the project design. Calculations can be found in appendix A.

- Main processor of the system is an Arduino Mega 2560. Features of the control board include: 54 Digital I/O pins, 16 Analog pins, 40 mA per I/O pin, 7 -12 V DC Input Voltage. This board is used to process signals from all inputs and cycle power to all output devices as needed.
  The original idea for the user interface was to use an Arduino compatible PCB, 4Duino. It is designed to have all the same functionality and dimensions as the Arduino UNO with a built in touchscreen. The Arduino UNO would not meet my requirements for the

number of I/O due to the amount of inputs a display required. The 4Duinoe system would be able to meet these requirements since the display was built into the system. I was able to learn how to program the display gadgets and use them to control LEDs on a breadboard. Once I started combining all the code for the sensors I found out that the 4Duino PCB would not support the required libraries for the AM2301 and RTC modules. At this point I had to scrap the idea of using the 4Duino PCB and implement a standard Arduino MEGA.

- Relay Control Board (RCB) – The primary function of the RCB is to energize a relay coil through a transistor circuit based on control signals from the processor. When the relay closes, contacts close to turn on the desired output device. Each relay is rated for up to 5 amps at 120 V_{AC}. The RCB is designed with 1 plug which provides 12V, 5V, and GND connections to be jumpered from the user interface PCB.
  The secondary function of the RCB is to be a single connection point for all of the input sensors. Each sensor has a 5V pin, GND pin and either 1 or 2 signal pins, depending on the sensor. The sensor signals will pass through the RCB to the processor.
  The 5V and GND planes are designed with a jumper to allow isolation from the power supply, if desired. The system operates with the jumpers installed allowing for 1 connection point from the Arduino PCB to the 5V and GND planes.

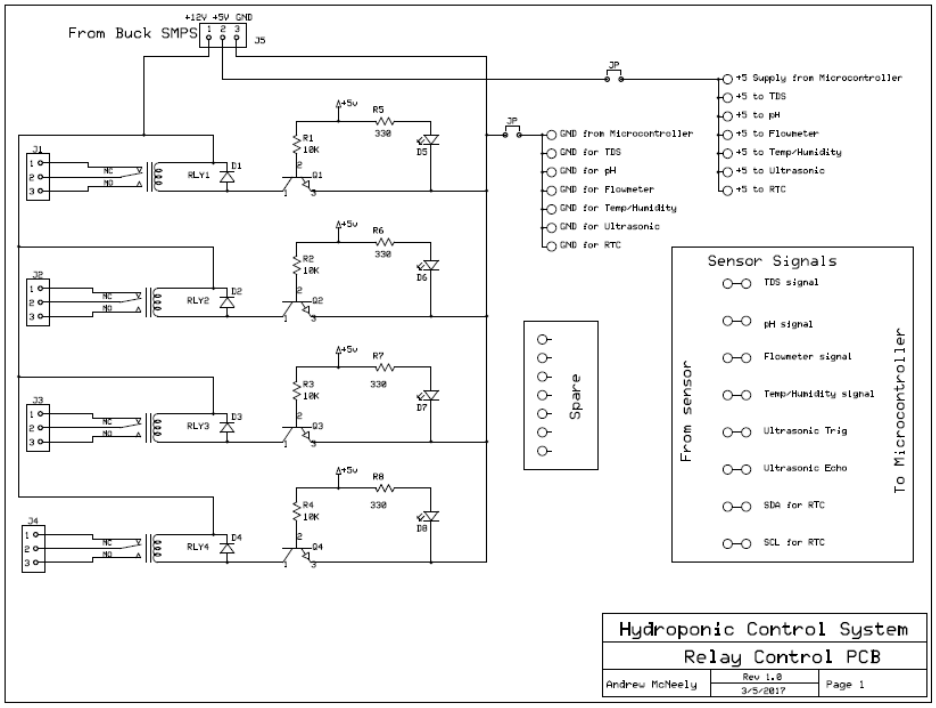

Figure 2 - Relay Control Board Schematic

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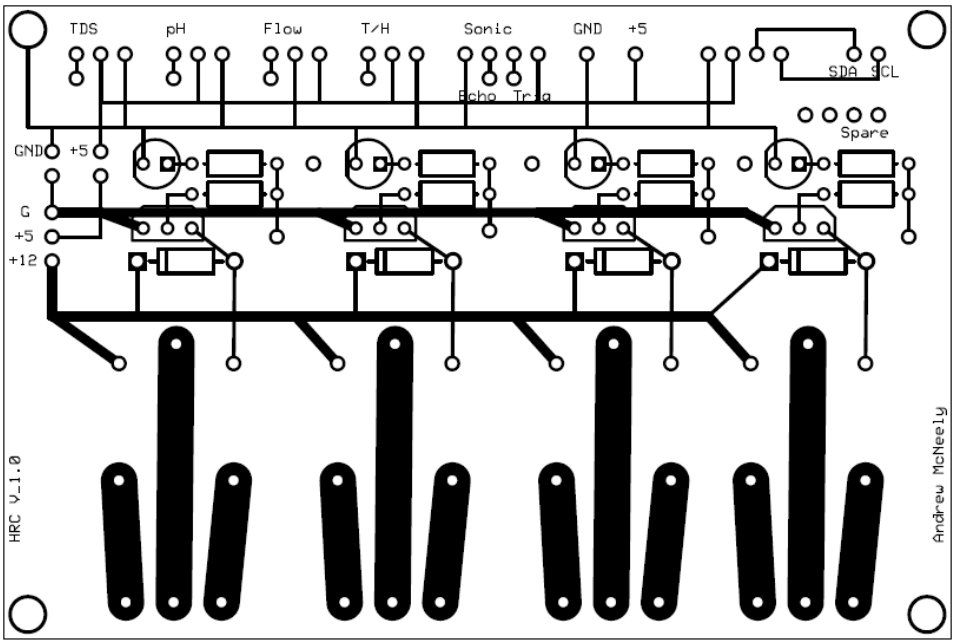

Figure 3 - Relay Control Board Layout

- Switch mode power supply (SMPS) – The function of the SMPS is to convert typical house power (120 V_{AC}) to usable 12V_{DC} required to run the relays and processor. The Arduino MEGA can accept 6-20V_{DC} but is recommended to stay within 7-12V_{DC} for proper operation. The Arduino processor outputs a regulated 5V_{DC} source to power the input sensors. A precise resistor feedback loop is required to supply the desired outputs. To allow for future adjustability, I placed a variable resistor in this feedback loop in lieu of standard resistors.
  The SMPS was originally designed to provide both, 12V_{DC} and 5.5V_{DC} regulated outputs. The 12V was designed to be utilized solely for the relay coil. The 5.5V was designed to provide input power to the 4Duino PCB, the original processor for the design. The 4Duino accepts a much narrower input voltage range than the Arduino MEGA. The 4Duino would have supplied the 5V needed to operate the input sensors. When the 4Duino was scrapped for certain reasons (described later in text), the 5.5V supply was no longer needed for the design. This happened after the PCB was printed and tested so the design was left in the documentation.

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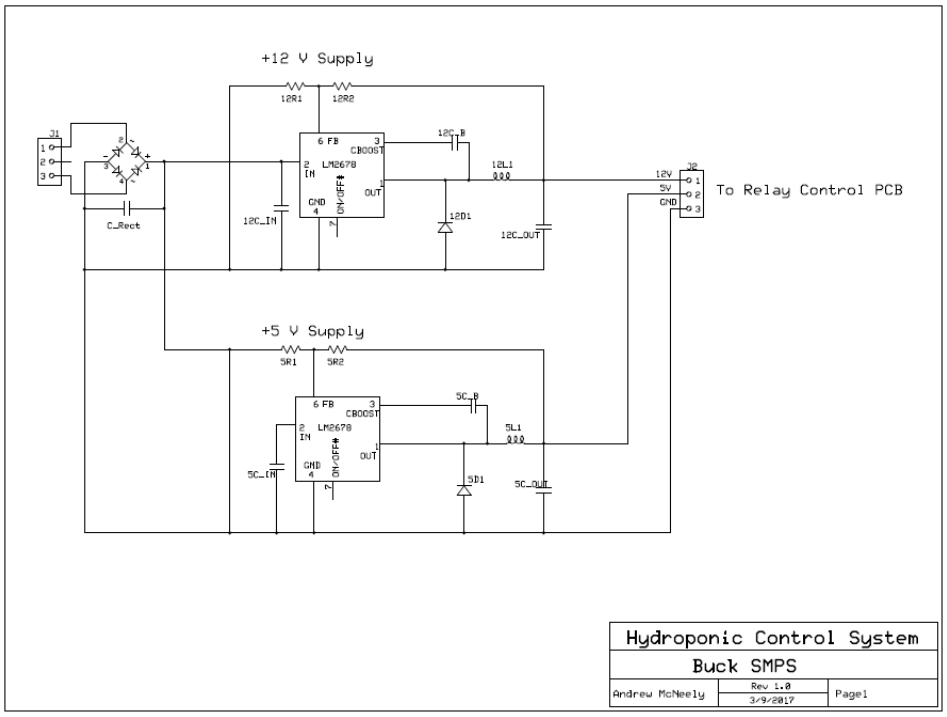

Figure 4 - Switch Mode Power Supply Schematic

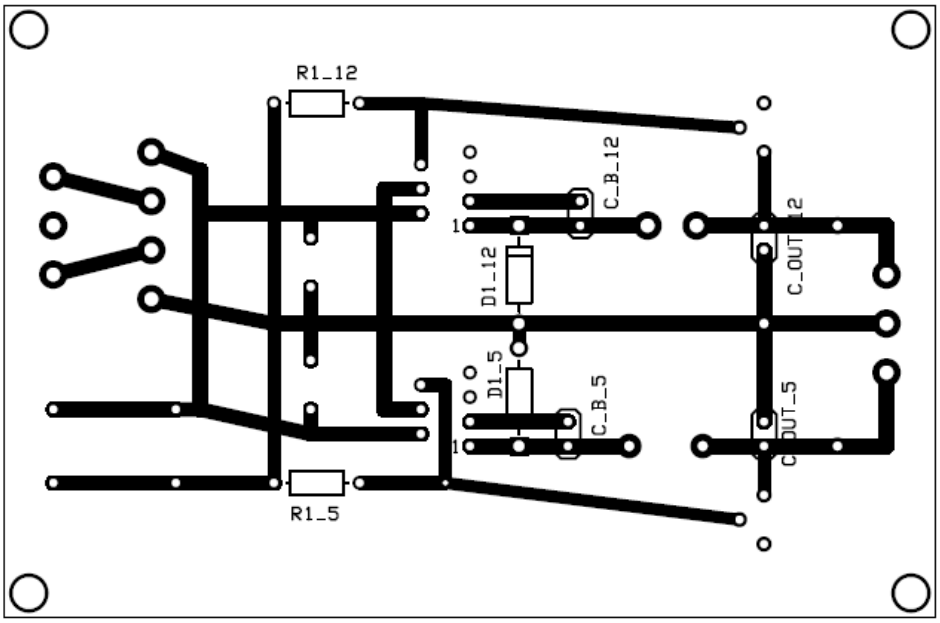

Figure 5 - Switch Mode Power Supply Layout

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- User Interface – The function of the user interface PCB is to provide a means of control for the user. It consist of a display that provides the user with visual information about the chemical make up of the water and the chemical requirements to meet specific setpoints. The user interface also provides 5 control push buttons. Two of these buttons perform control functions and three of the buttons are used to display various information needed for the system to function properly. The user interface contains 2 plugs on the board, one for the 12V supply from the power supply PCB and another plug to jumper 12V and 5V to the relay control board. The board contains a ground plane and a 5V plane, both of which are connected to the Arduino to allow for a complete path for all of the sensors and relay controls.
  Since this PCB was designed late in the design process, it's dimensions are the same as the relay control board to allow for stacking in the control box. Holes in the user interface allow the user to clearly see indicating LEDs on the relay control board which sits directly below the user interface board.

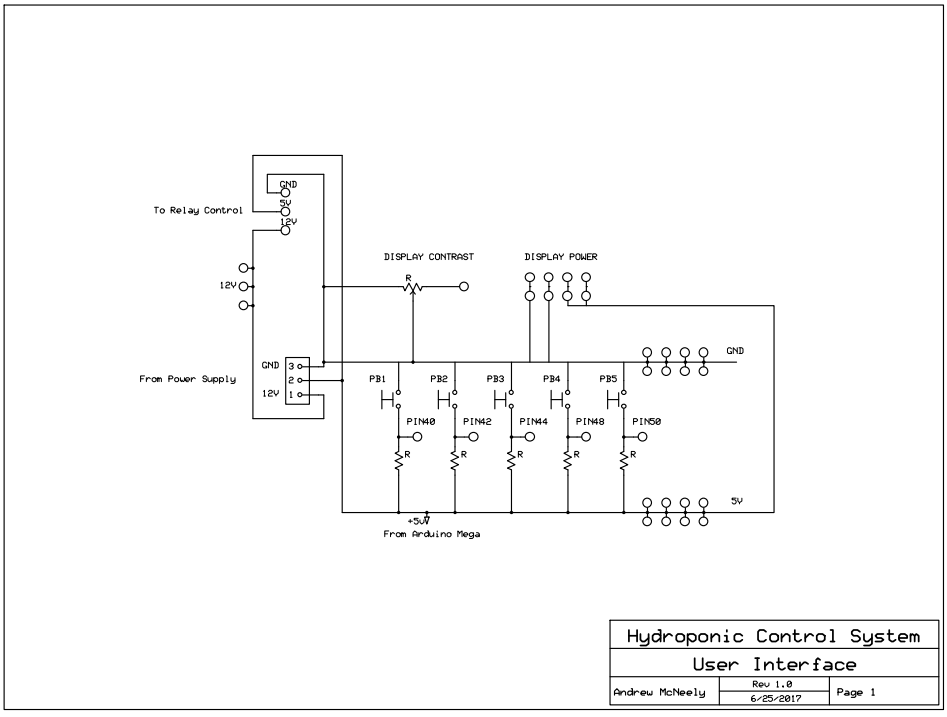

Figure 6 - User Interface Schematic

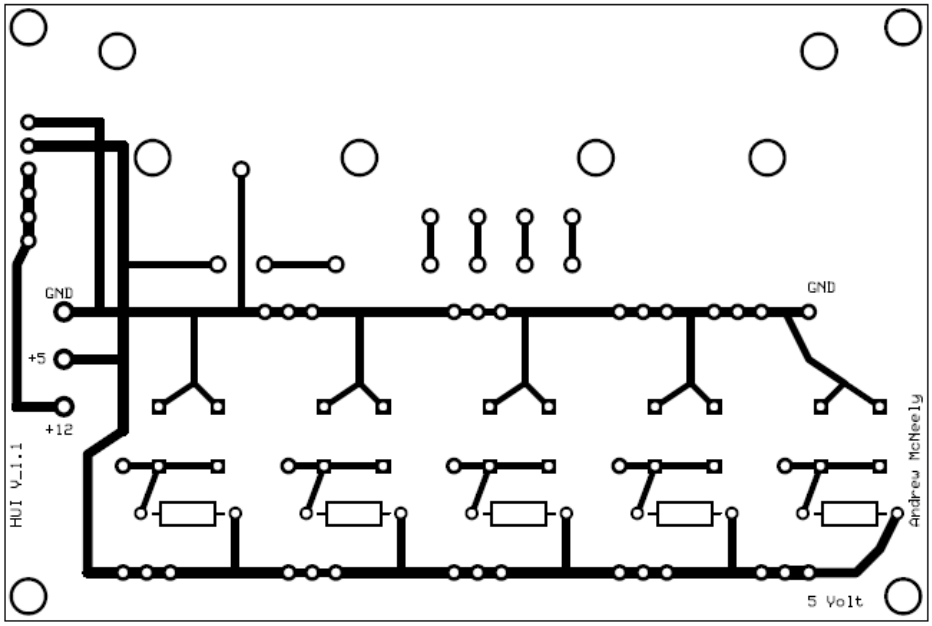

Figure 7 - User Interface Layout

3.3 **Software**

The project code is written in C language using the Arduino IDE. Portions of the code are implemented using examples from the Arduino learning playground. Libraries that are utilized within the project code include:

- LiquidCrystal.h – Used to properly display characters on the system display.
- Wire.h – Used to allow the use of the I2C bus.
- RTClib.h – Used to implement a real time clock.
- DHT.h – Used with the AM2301 temperature and humidity sensor.

The project code was written for each sensor individually and tested on an Arduino UNO prior to compiling it into a single project file. This allowed for easy troubleshooting and calibration of each sensor if required.

The pH and Analog EC sensors are not considered industrial grade sensors and thus cannot be left in the liquid for long periods of time. This had to be considered when writing the project code. During my trial and error of working around this issue, I was able to implement a pre-test sequence that would hard code the system to a pre-test state. After a short time delay, required to allow the sensors time to soak in the reservoir, the system would automatically place itself in test mode, perform the test, and display the results.

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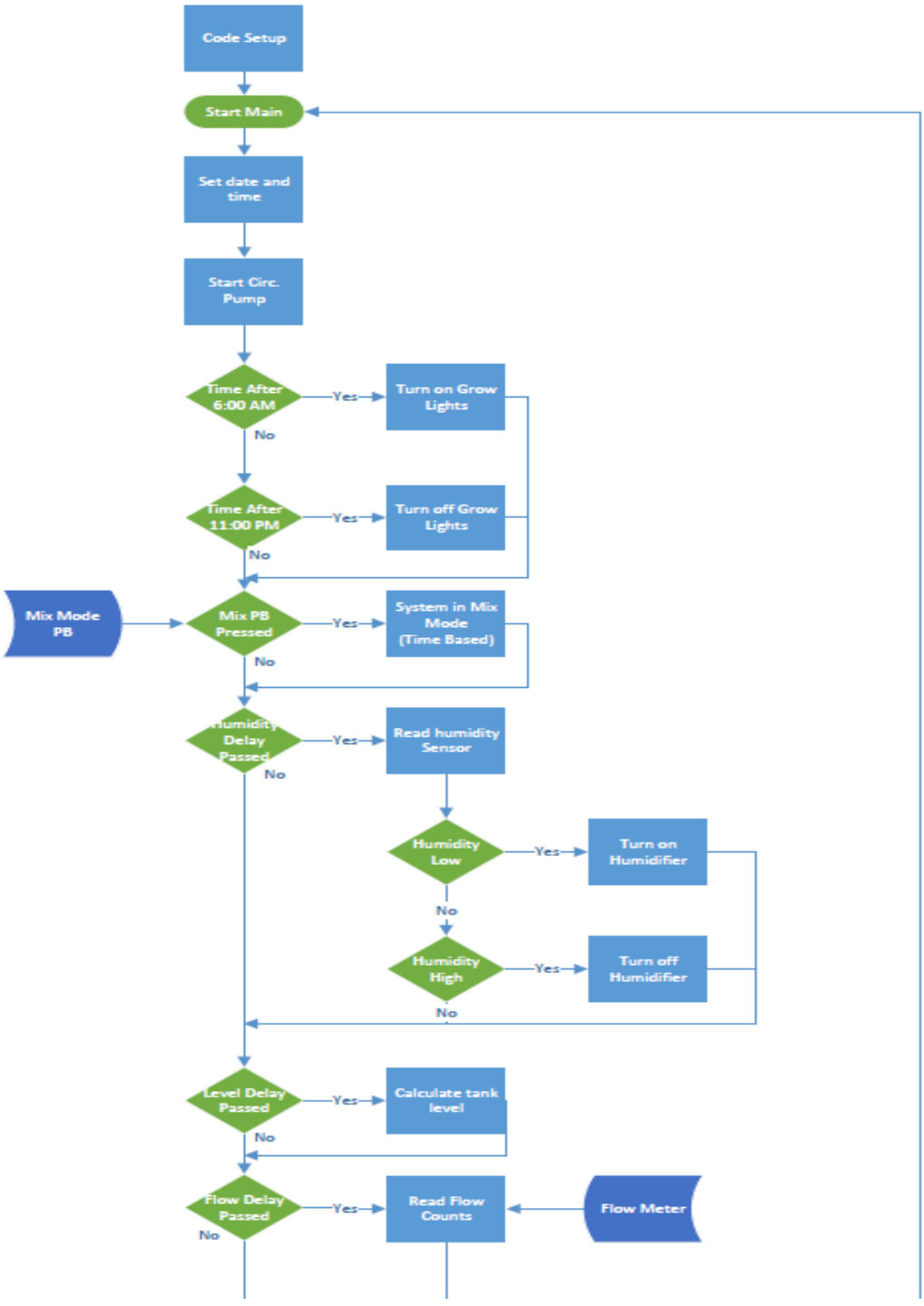
3.4 Software Overview



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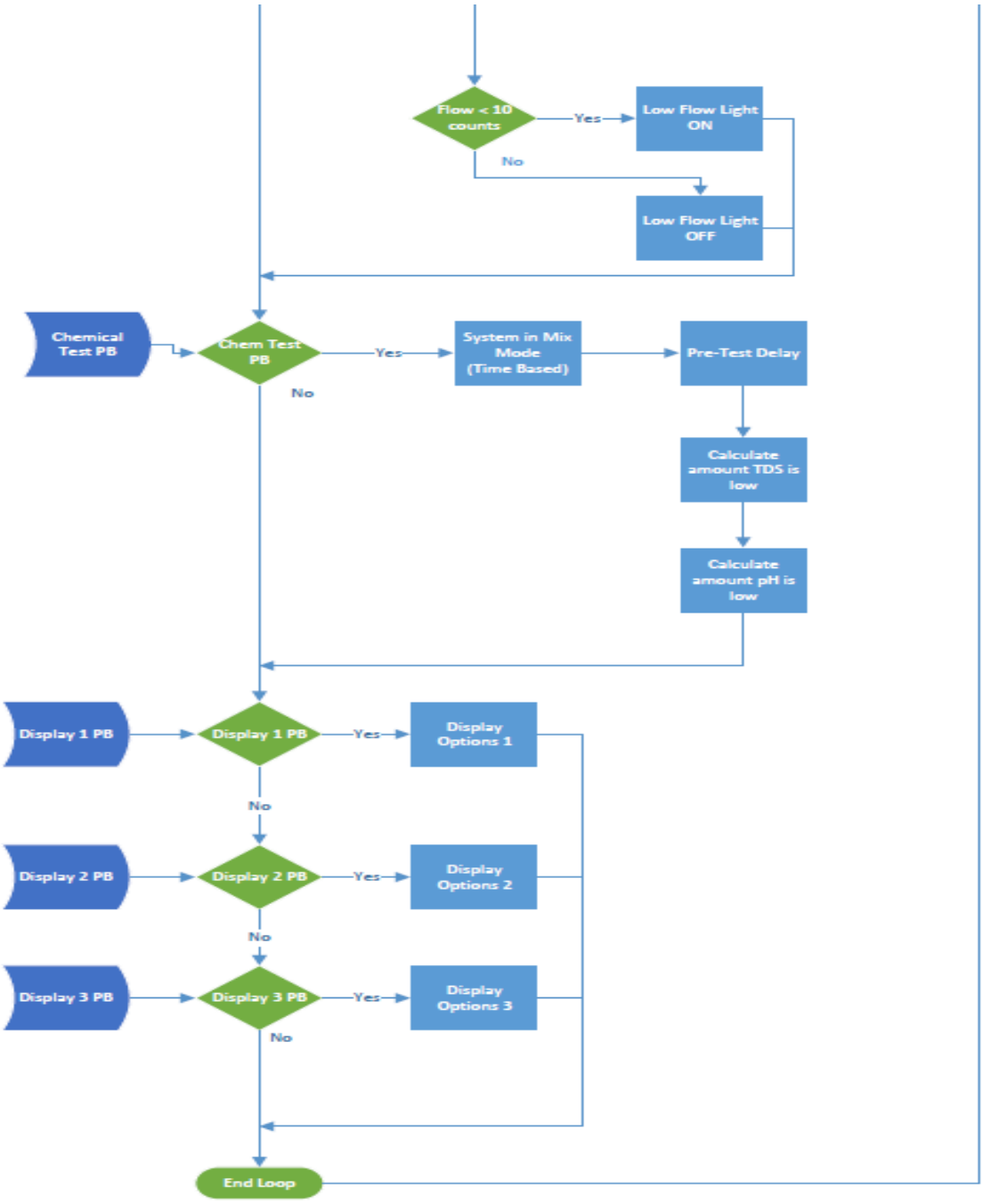

Figure 8 - Software Overview

3.5 **Interface**

The system user will interface with the control system using the information provided on the display and the 5 pushbuttons provided on the user interface board. The display has 3 measurement pages to display the required data to allow for proper adjust of the system to maintain proper grow environment.

Display option 1 shows the humidity of the surrounding environment and the level of the reservoir. The humidifier will cycle on at 60% and off at 70% humidity. The chemical test will be aborted if the level is below 9 inches. This is due to the length of the sensors in the reservoir.

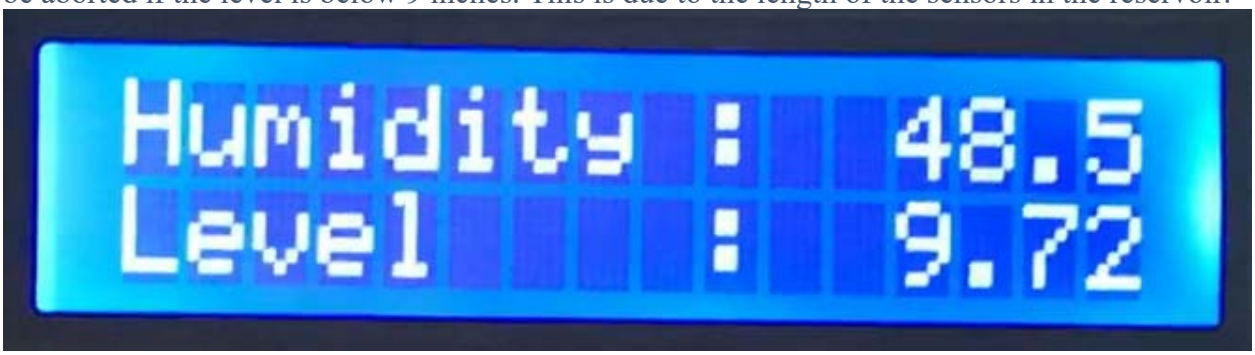

Figure 9 - Display Option 1

After the initial chemical test, display option 2 will display the ppm and pH readings of the system. Prior to any test, this display window will show default readings as seen below.

Figure 10 - Display Option 2

Display option 3 will show the amount of each chemical that needs to be added to the system to maintain a proper chemical makeup of the water. The chemical makeup requirement changes weekly. These requirements are taken from Emerald Harvest 3 part nutient series. The amounts displayed are in milliLiters. If no chemical test has been completed on the system, display option 3 will not show any data.

Figure 11 - Display Option 3

The user inteface board has 5 pushbuttons used to control the system. From left to right:
Mix Mode , Chemical Test Mode , Display 1, Display 2, Display 3

Figure 12 - User Interface pushbuttons

The original plan was to implement the 4Duino with a built in touchscreen. When that idea was scrapped and I started implementing the Arduino MEGA as the processor, I needed a new way to display and control the system. I had access to a 2 * 16 LCD display that would be able to display enough information for the system to function correctly. I was able to design and test a circuit board that consisted of pushbutton circuitry and display hook-ups quickly. These actions allowed for my design to incorporate the required user interface.

4. SYSTEM ARCHITECTURAL DESIGN

4.1 System Inputs

- SEN0161 Analog pH meter

5V operating voltage
Range 0-14

Accuracy + 0.1
Response time < 1 min
Potentiometer adjustable gain

Since the pH sensor is a linear sensor it could be calibrated by obtaining a few data points and creating a trend line. The below graph shows the test points and the resulting trend line. This equation was used in the project code to determine the pH of the water system.

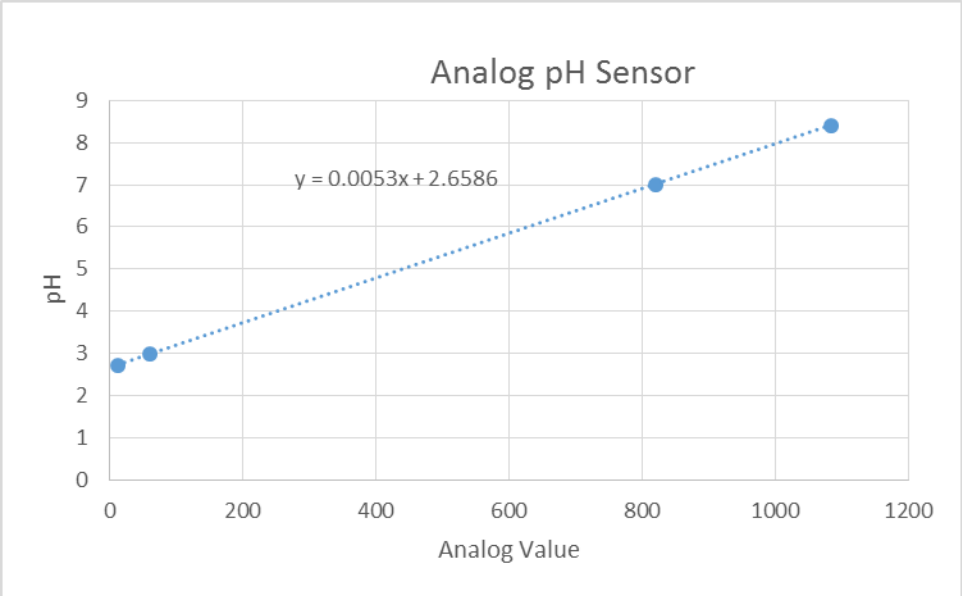

Table 2 - pH Sensor Calibration

- Gravity: Analog Electrical Conductivity (EC) Sensor

5V operating voltage
Range 1ms/cm – 20ms/cm (640-1280 ppm)
Accuracy < + 10%

Since the EC sensor is a linear sensor it could be calibrated by obtaining a few data points and creating a trend line. The below graph shows the test points and the resulting trend line. This equation was used in the project code to determine the TDS of the water system.

Due to the length of the pH and EC sensors, the height of the reservoir needs to be above 9 inches for a chemical test to run successfully. If the level is below 9 inches, the sensors run the risk of not being covered in water and may give erroneous readings.

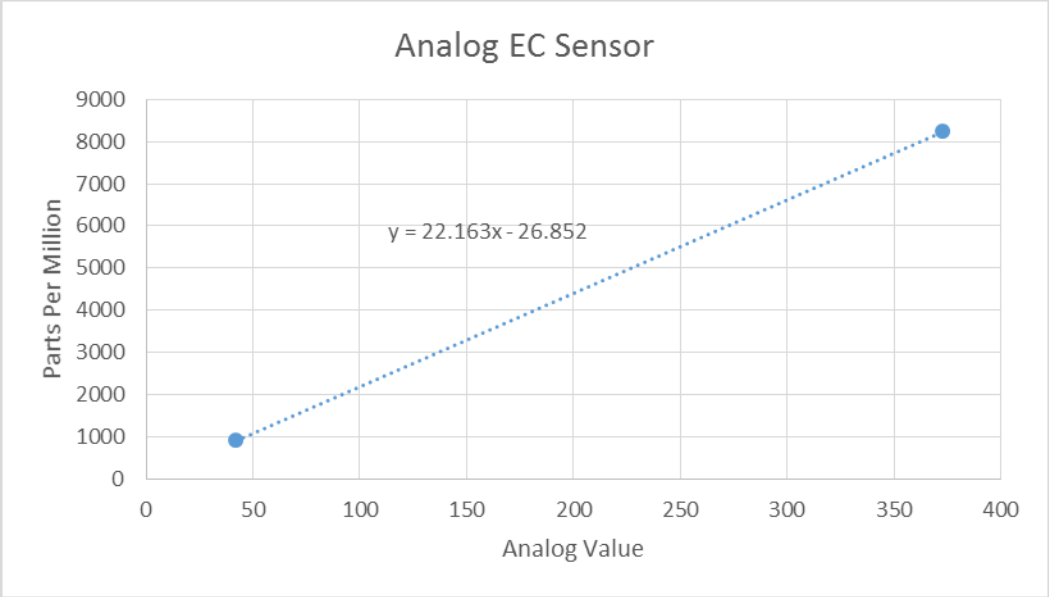

Table 3 - TDS Sensor Calibration

- HC-SR04 Ultrasonic Ranging

5V operating voltage
15mA operating current
Range 2cm-4m
Measuring Angle – 15 degrees
Trigger signal – 10uS pulse

The ultrasonic ranging device is used to measure the depth of the water in the reservoir. The system will trigger the ranging device and calculate the volume of the reservoir based on the returned echo signal (See Figure 13). The reservoir volume is used to determine the system volume and the amount of nutrients needed for the system to maintain a healthy growing environment.
The sensor technically measures the distance from the top of the reservoir to the waterline. A simple subtraction from the height of the reservoir shows the water level of the reservoir. Multiplying this height by a constant based on the radius of the reservoir, I was able to calculate the volume of the system.

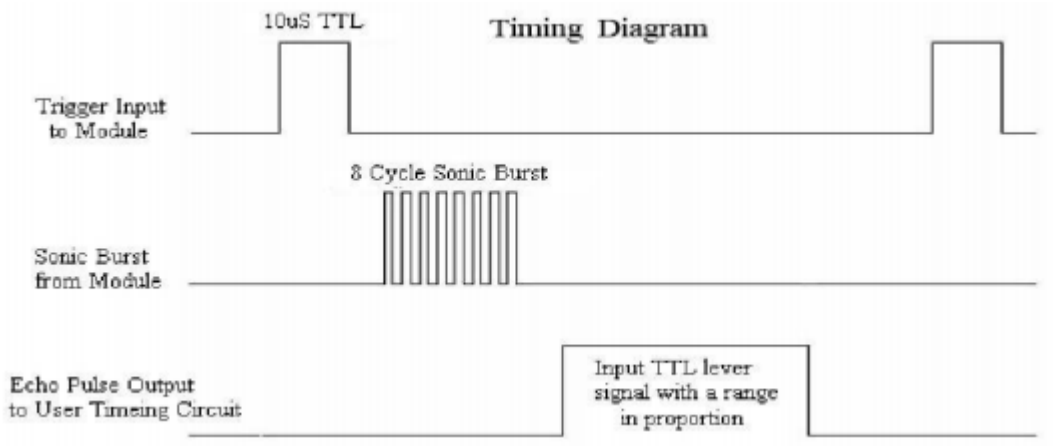

Figure 13 - Ultrasonic Timing Diagram

- AM2301 Temperature and Humidity module

3.3-5.2V operating voltage
500uA operating current
Sampling period – 2 seconds

The system is designed to operate within a temperature controlled environment therefore temperature monitoring in not needed. The humidity of the grow room should be maintained between 60%-70%. The system will monitor humidity and control a humidifier to maintain level within spec.

- Electronic Hall Effect Water Flow Counter Sensor

3-18V operating voltage
Flow range 0.1-4.5 L/min

For the system to be functional, continuous flow is needed. The plants will dry out and die if their root systems do not have a source of water. If a no flow condition is detected, an LED will illuminate on the control box as a visual indication of a problem.

4.2 System Outputs

- Grow lights

120 operating voltage
21mA operating current
2W power consumption

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The grow lights are used to supply the plants with a full spectrum of light. The lights are cycled on and off by the processor. The light cycle turns on at 6:00 AM and will turn off at 11:00 PM.

- Circulation pump / Mix Pump

ActiveAQUA AAPW40 submersible pump
120V operating voltage
50mA operating current
4W power consumption
Pump lift 0-2.8 feet
Flow rate 0 – 5.8 L/min

The circulation pumps maintain a constant flow of nutrient water from the reservoir to the grow trough. The system monitors uses a flow counter to ensure flow is happening. If not, the system will illuminate a low flow LED.

The mix pump is used to mix the water in the reservoir prior to conducting a chemical test. This is to ensure that the suspended solids in the water do not settle on bottom of the reservoir.

- Humidifier

Black & Decker BXHU090 humidifier
120V operating voltage
125 ma operating current
12W power consumption.
875 mL tank size / 8 hours runtime

The humidifier will cycle on and off to ensure the humidity of the grow room stays within the desired humidity levels. A run time timer will illuminate an indicator when the humidifier reaches 7 hours of run time to ensure it does not run dry.

I had trouble finding a humidifier with a low enough power draw that enabled my system to power it and was not controlled via a microprocessor. The microprocessor based humidifiers would always turn off when power was cycled to them and would require a user to press the button to start the humidifier. Since I needed to be able to cycle power to the humidifier and have it start up with no user intervention I had to modify the humidifier I had. I soldered a jumper around the pushbutton of the control PCB and tested to verify the operation. This allowed for the humidifier to be controlled by my control system with no user intervention.

4.3 Concept of execution

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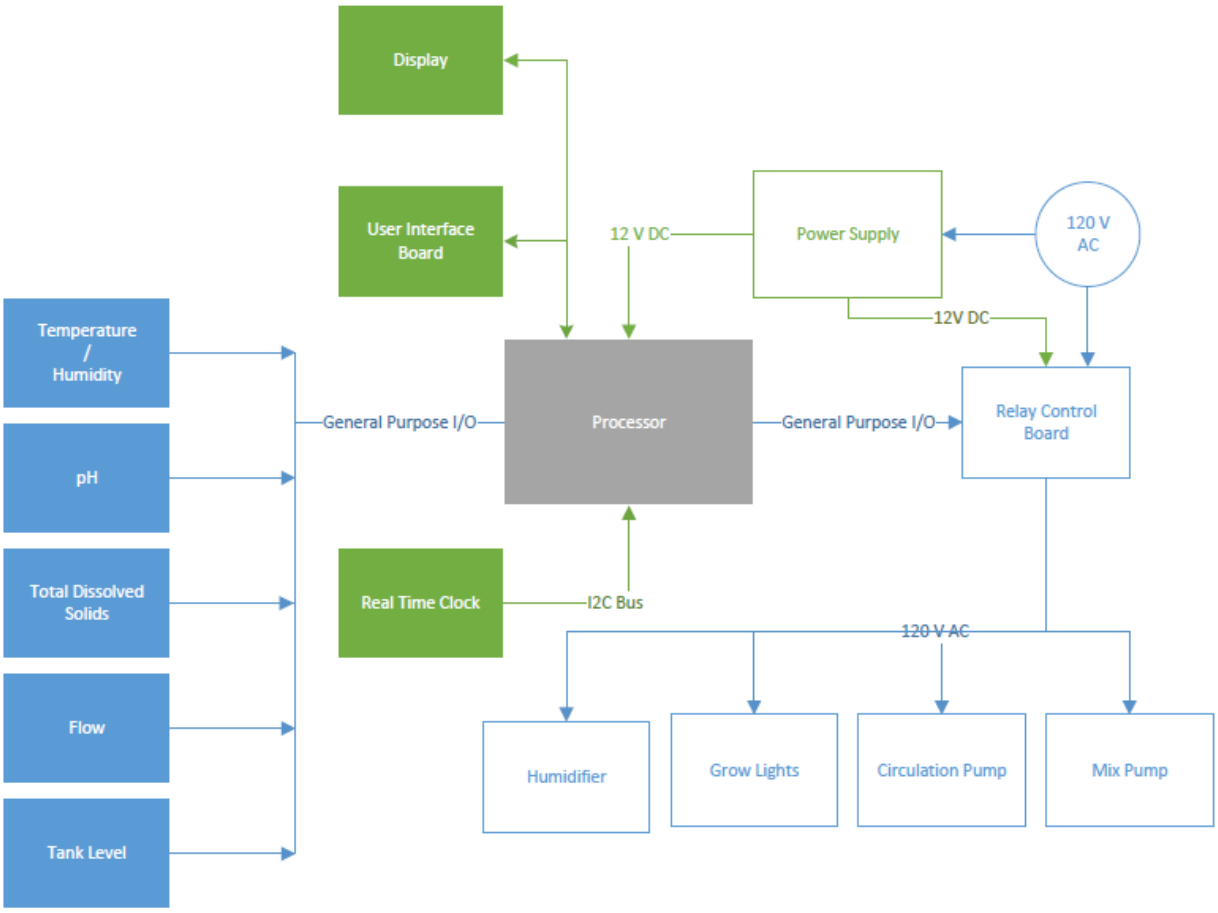


Figure 14 - System One line

The power flow for the system starts with a typical 120V outlet. The system splits this 120 source in 2 paths, one to be converted to DC voltages and one to power the outputs. The power supply takes the 120V input through a step down and rectification circuitry. This rectified signal is passed through a regulator to provide a steady 12V DC used to power the processor and energize the relays, and 5 V DC used to power the sensors.

The system is designed with 5 input sensors. Each requiring a 5V power source to operate. These sensors monitors an aspect of the grow environment and sends this information back to the main processor.

The processor makes decisions based on the inputs received from the 5 sensors and a RTC. It will update the display with the desired information and send control signals to the relay control board to energize/de-energize the system outputs.

The system is designed with 4 output devices to aid in controlling the grow environment. Each of these outputs require a 120 V source to operate.

4.4 Interface design

The system is monitored and controlled using the User Interface PCB. The User Interface consist of 5 pushbuttons. Two of the pushbuttons place the system into different modes of operation and three pushbuttons change the readings that are displayed.

PB1 – Places the system into Mix mode.
PB2 – Places the system into Test mode. System can only enter Test mode if the reservoir level is greater than 9 inches.
PB3 – Displays system Humidity and Volume. This information is updated every 5 seconds due to a built in sensor delay.
PB4 – Displays system ppm and pH levels. This information is only updated after the system has run through a test sequence.
PB5 – Displays required amount of chemicals that need to be added to system to maintain a proper grow environment. This page is only available after the system has completed an initial Test sequence.

5. System Setup

The system must be cleaned and set up proper before it can be placed into service. This is to ensure that no leftover residue remains in the system to contaminate the next grow cycle.

- Empty reservoir and thoroughly clean.
- Fill reservoir past the 9 inch mark.
- Place reservoir back into system and cover with lid.
- Ensure the humidifier tank is full.
- Using the Arduino IDE, ensure the date and time are properly set.
- Power up the system.

6. System Operation

The system must be maintained on a daily basis. This is to ensure that a proper grow environment is maintain to allow the best results of your plants.

- Ensure the low flow LED is not illuminated.
- Ensure the humidifier tank is not empty. Fill as needed.
- If during the day, ensure all grow lights are illuminated. Replace as needed.

- Check level measurement on page 1. Fill reservoir as needed.
- Place the system into mix mode to ensure the water is properly mixed for chemical test.
- Place the pH and TDS sensors into reservoir.
- Place the system into test mode.
- Check the results on page 3.
- Add chemicals as needed.

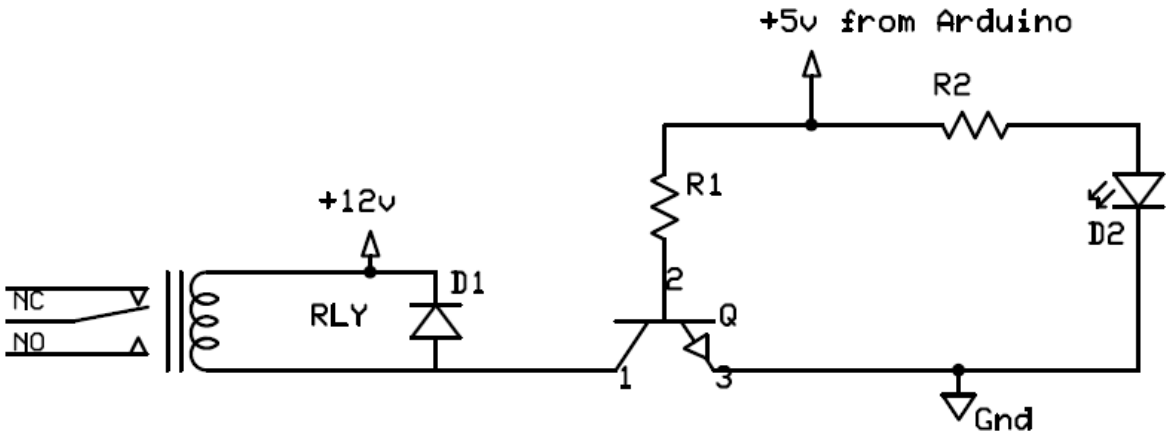
7. CONCLUSIONS AND RECOMMENDATIONS

Throughout the design process I was able to work through several road blocks and was able put together a working prototype of a hydroponic system. Due to unexpected circumstances, a few items were either modified or marked of the features list altogether. Although the final product is not exactly as I had envisioned it at the start of this process, it is does meet all of the required functionalities for a working prototype.

Appendix A
System Calculations

System Calculations:

1. Relay Control Board
   a. Using a $5V_{dc}$ signal from the Arduino control board to close a $12V_{dc}$ relay coil. An LED is used in parallel with the circuitry to provide a visual indication of the relay state.
   b. The circuit utilizes an NPN transistor to connect the negative side of the 12V relay to ground, completing the circuit.
   c. Calculations required are for R1 and R2 to ensure a maximum of 20 mA (for the 4Duino PCB[1]) is used for this circuitry.



   d. R1 Calculations
      i. $R_{coil} = 375\ \Omega \Rightarrow I_{coil} = 12V / 375\ \Omega = 32$ mA.

         This 32 mA is the collector current of the NPN transistor.

      ii. Gain of the transistor = 75 $\Rightarrow I_b = I_c/75 = 0.426$ mA.

         This 0.426 mA is the base current of the transistor required to forward bias the transistor.

      iii. $R1 = 5V / I_b = 11737\Omega$.

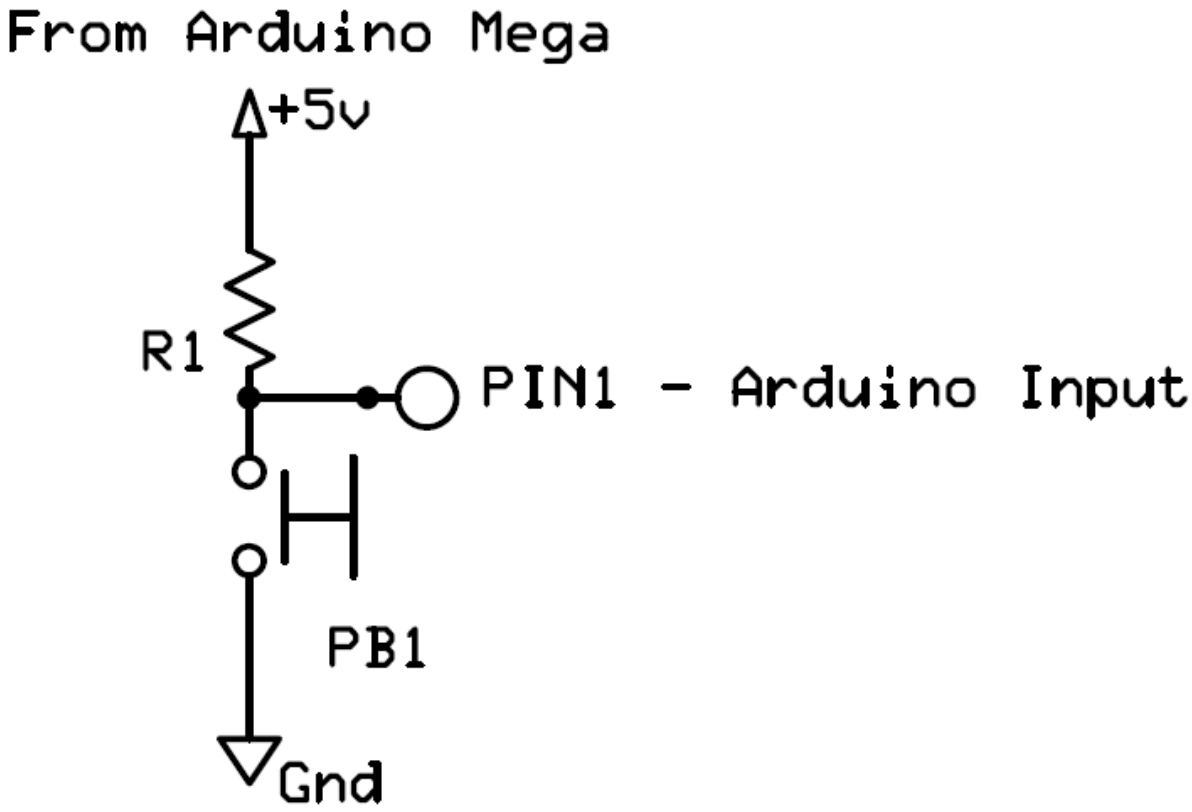
         A 10k Ω resistor was chosen for R1, resulting in an I_b of 0.5 mA from the Arduino.

   e. R2 Calculations
      i. Size for R2 determined by maximizing the current through D2 while not exceeding 20 mA limit of the Arduino output pins. Current of 15 mA chosen to provide a margin of error.
      ii. $15\text{ mA} = (5V - 0.7V_{LED}) / R2 \Rightarrow R2 = 286\ \Omega$.

[1] 4Duino PDB not used for final project design due to lack of compatibility with required libraries. Relay control board was designed, built, and tested when processor changed.

A 330 Ω resistor was chosen for R2, resulting in a 13 mA draw from the Arduino.

2. User Interface Board
    a. Using a 5Vdc signal from the Arduino control board to input user selections via pushbuttons.
    b. The circuit utilizes a pull-up resistor concept which applies 5V to the input pin when button is not pressed and connects the input pin to ground when the button is pressed.
    c. Calculations required for R1 to meet a desired current of 1mA through each pushbutton circuit.



    d. R1 Calculations:
        i. R1 = 5V / 1 mA = 5k Ω.

        A 6.6k Ω resistor was chosen, resulting in a current of 0.75mA. The resistor size was due to the urgency of the User Interface board and the on-hand components.

3. 12V Switch Mode Power Supply

a. Calculations for the 12V SMPS are taken from section 8.2.3 Adjustable Output Design Example of the LM2676 technical specification sheet.

b. Step 1: Define operation conditions
   i. V_{out} = 12 V_{dc}
   ii. V_{in} max = 37 V_{dc}
   iii. I_{load} max = 1A

c. Step 2: Feedback resistor size
   i. $V_{out} = V_{fb} (1 + R1/R2)$
      1. V_{fb} = 1.21 V
      2. R1= 1k Ω (typical)
   ii. R2 = [(12 / 1.21) – 1] * 1000 = 8.9 k Ω

   A 10k Ω variable resistor used in lieu of a set resistor to allow for minor adjustments to output voltage.

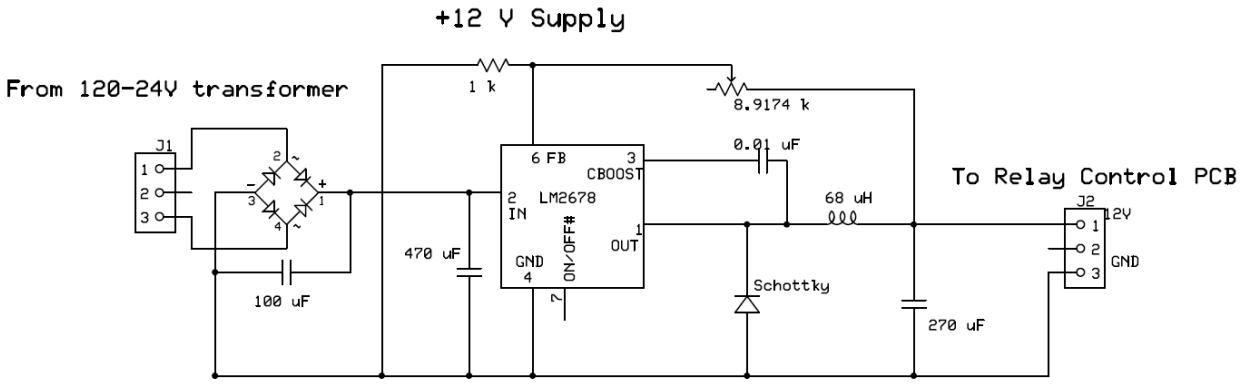
d. Step 3: Calculate inductor Volt * microsecond constant to determine inductor size
   i. $E*T = (V_{in} max – V_{out} – V_{sat}) * (V_{out} + Vd)/(V_{in} max – V_{sat} + V_d) * (1000/260)$
   ii. E*T = (37-12-0.12) * (12+0.5) / (37-0.12+0.5) * (1000/260)
      1. E*T = 23.427
      2. This correlates to section L30 of figure 20.
      3. Inductor size chosen for this power supply is 68uH, 1.71A

e. Step 4: Determine output capacitor
   i. Using 12V out and inductor size of 68uH
   ii. 270uF with a I_{rms} of 0.6A rating capacitor chosen from chart

f. Step 5: Determine input capacitor
   i. Using 37 Vdc and 0.5A I rating
   ii. 470uF, 50V, 1.44A capacitor chosen from chart

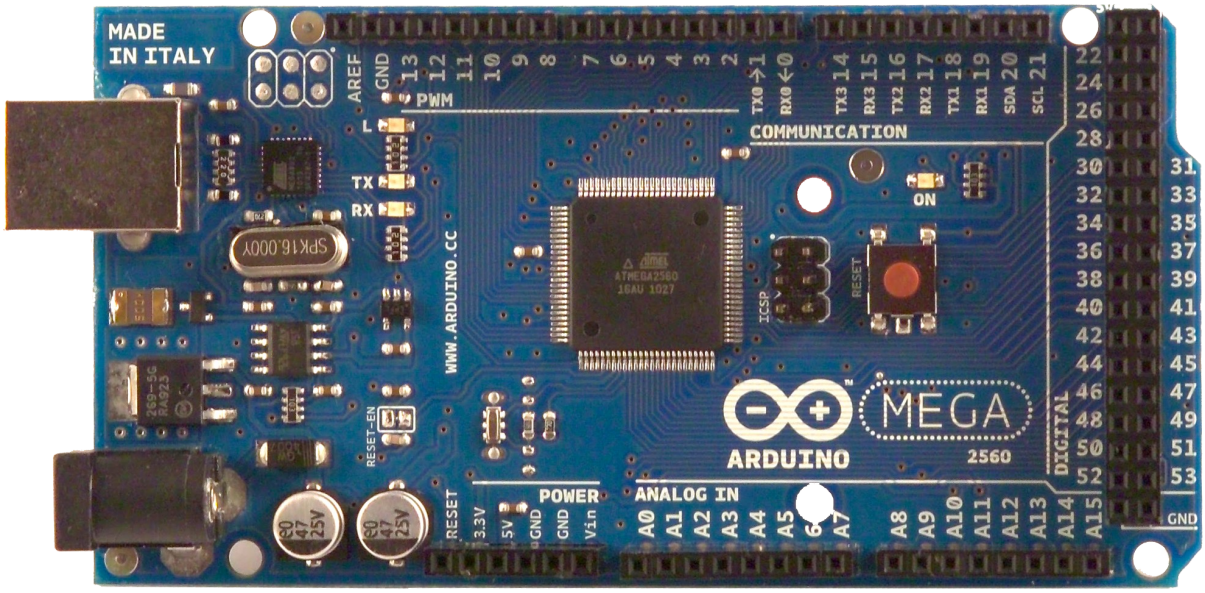
g. Step 6: Determine Schottky diode – 5A through hole 1N5825 chosen

h. Step 7: Use a 0.01uF capacitor for C_{boost}



Appendix B
Arduino Mega 2560

Arduino MEGA 2560



Product Overview

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560 (datasheet). It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove or Diecimila.

Index

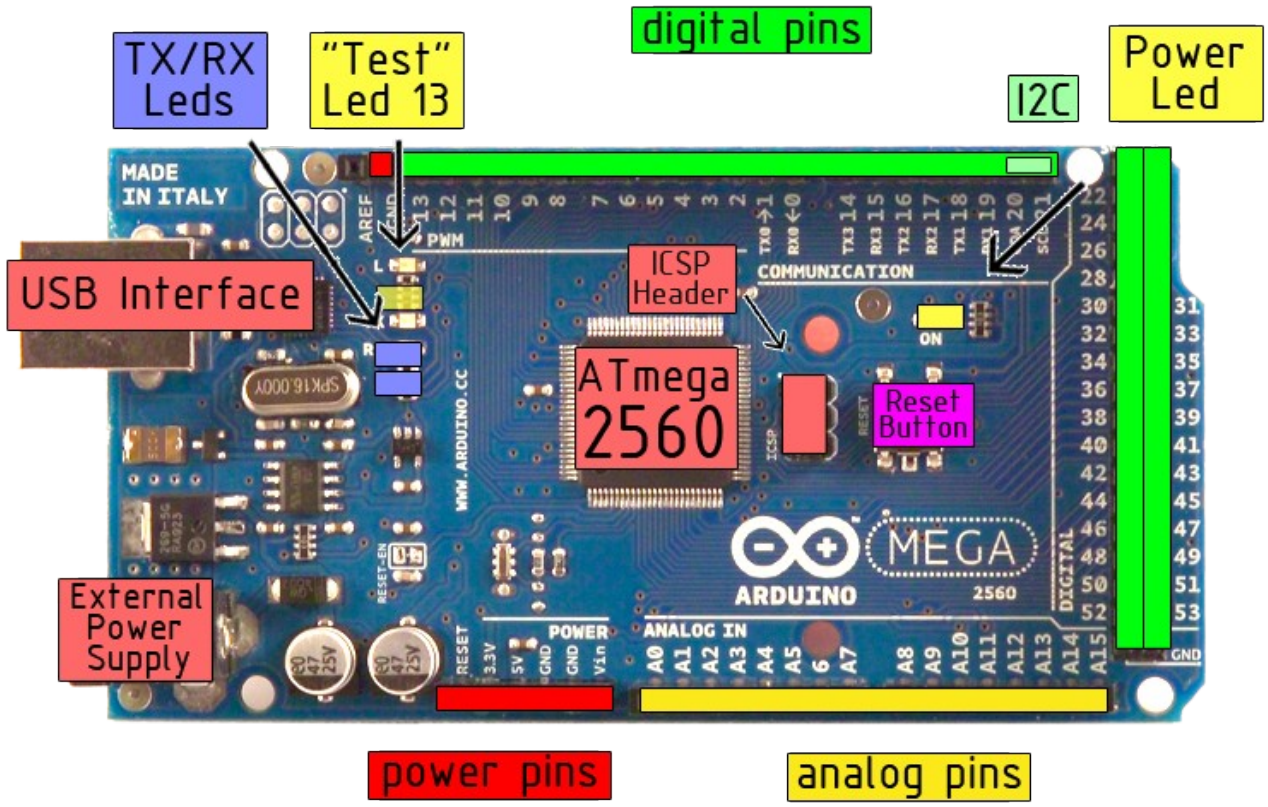
Technical Specification

EAGLE files: arduino-mega2560-reference-design.zip Schematic: arduino-mega2560-schematic.pdf

Summary

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54 (of which 14 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

the board



Power

The Arduino Mega2560 can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The Mega2560 differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter.

The power pins are as follows:

- **VIN.** The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- **5V.** The regulated power supply used to power the microcontroller and other components on the board. This can come either from VIN via an on-board regulator, or be supplied by USB or another regulated 5V supply.
- **3V3.** A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- **GND.** Ground pins.

Memory

The ATmega2560 has 256 KB of flash memory for storing code (of which 8 KB is used for the bootloader), 8 KB of SRAM and 4 KB of EEPROM (which can be read and written with the EEPROM library).

Input and Output

Each of the 54 digital pins on the Mega can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

- **Serial: 0 (RX) and 1 (TX); Serial 1: 19 (RX) and 18 (TX); Serial 2: 17 (RX) and 16 (TX); Serial 3: 15 (RX) and 14 (TX).** Used to receive (RX) and transmit (TX) TTL serial data. Pins 0 and 1 are also connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip .
- **External Interrupts: 2 (interrupt 0), 3 (interrupt 1), 18 (interrupt 5), 19 (interrupt 4), 20 (interrupt 3), and 21 (interrupt 2).** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.
- **PWM: 0 to 13.** Provide 8-bit PWM output with the analogWrite() function.
- **SPI: 50 (MISO), 51 (MOSI), 52 (SCK), 53 (SS).** These pins support SPI communication, which, although provided by the underlying hardware, is not currently included in the Arduino language. The SPI pins are also broken out on the ICSP header, which is physically compatible with the Duemilanove and Diecimila.
- **LED: 13.** There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.
- **I^2C: 20 (SDA) and 21 (SCL).** Support I^2C (TWI) communication using the Wire library (documentation on the Wiring website). Note that these pins are not in the same location as the I^2C pins on the Duemilanove.

The Mega2560 has 16 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and analogReference() function.

There are a couple of other pins on the board:

- **AREF.** Reference voltage for the analog inputs. Used with analogReference().
- **Reset.** Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

Communication

The Arduino Mega2560 has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega2560 provides four hardware UARTs for TTL (5V) serial communication. An ATmega8U2 on the board channels one of these over USB and provides a virtual com port to software on the computer (Windows machines will need a .inf file, but OSX and Linux machines will recognize the board as a COM port automatically. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the board. The RX and TX LEDs on the board will flash when data is being transmitted via the ATmega8U2 chip and USB connection to the computer (but not for serial communication on pins 0 and 1).

A SoftwareSerial library allows for serial communication on any of the Mega's digital pins.

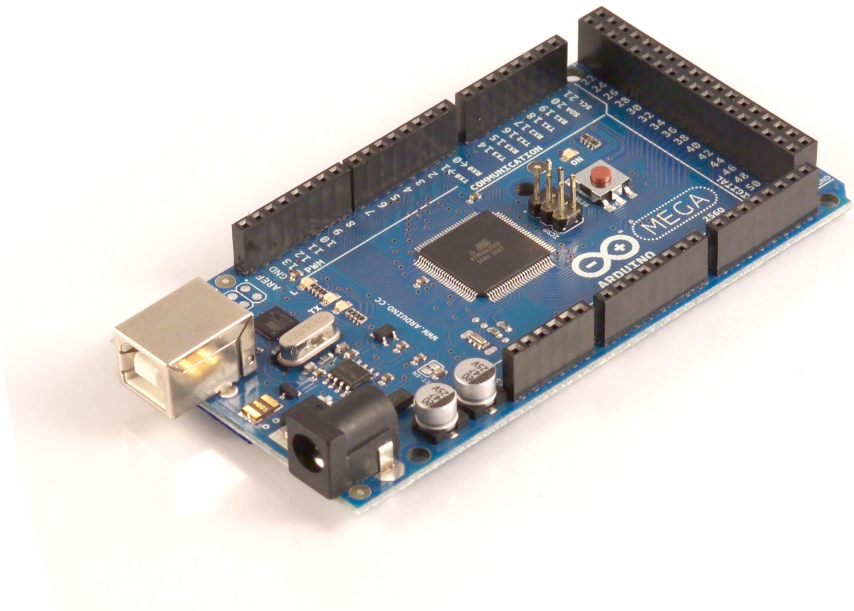
The ATmega2560 also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus; see the documentation on the Wiring website for details. To use the SPI communication, please see the ATmega2560 datasheet.

Programming

The Arduino Mega2560 can be programmed with the Arduino software (download). For details, see the reference and tutorials.

The Atmega2560 on the Arduino Mega comes preburned with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference, C header files).

You can also bypass the bootloader and program the microcontroller through the ICSP (In-Circuit Serial Programming) header; see these instructions for details.



Automatic (Software) Reset

Rather then requiring a physical press of the reset button before an upload, the Arduino Mega2560 is designed in a way that allows it to be reset by software running on a connected computer. One of the hardware flow control lines (DTR) of the ATmega8U2 is connected to the reset line of the ATmega2560 via a 100 nanofarad capacitor. When this line is asserted (taken low), the reset line drops long enough to reset the chip. The Arduino software uses this capability to allow you to upload code by simply pressing the upload button in the Arduino environment. This means that the bootloader can have a shorter timeout, as the lowering of DTR can be well-coordinated with the start of the upload.

This setup has other implications. When the Mega2560 is connected to either a computer running Mac OS X or Linux, it resets each time a connection is made to it from software (via USB). For the following half-second or so, the bootloader is running on the Mega2560. While it is programmed to ignore malformed data (i.e. anything besides an upload of new code), it will intercept the first few bytes of data sent to the board after a connection is opened. If a sketch running on the board receives one-time configuration or other data when it first starts, make sure that the software with which it communicates waits a second after opening the connection and before sending this data.

The Mega contains a trace that can be cut to disable the auto-reset. The pads on either side of the trace can be soldered together to re-enable it. It's labeled "RESET-EN". You may also be able to disable the auto-reset by connecting a 110 ohm resistor from 5V to the reset line; see this forum thread for details.

USB Overcurrent Protection

The Arduino Mega has a resettable polyfuse that protects your computer's USB ports from shorts and overcurrent. Although most computers provide their own internal protection, the fuse provides an extra layer of protection. If more than 500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed.

Physical Characteristics and Shield Compatibility

The maximum length and width of the Mega PCB are 4 and 2.1 inches respectively, with the USB connector and power jack extending beyond the former dimension. Three screw holes allow the board to be attached to a surface or case. Note that the distance between digital pins 7 and 8 is 160 mil (0.16"), not an even multiple of the 100 mil spacing of the other pins.

The Mega is designed to be compatible with most shields designed for the Diecimila or Duemilanove. Digital pins 0 to 13 (and the adjacent AREF and GND pins), analog inputs 0 to 5, the power header, and ICSP header are all in equivalent locations. Further the main UART (serial port) is located on the same pins (0 and 1), as are external interrupts 0 and 1 (pins 2 and 3 respectively). SPI is available through the ICSP header on both the Mega and Duemilanove / Diecimila. **Please note that I^2C is not located on the same pins on the Mega (20 and 21) as the Duemilanove / Diecimila (analog inputs 4 and 5).**

How to use Arduino

Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. The microcontroller on the board is programmed using the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing). Arduino projects can be stand-alone or they can communicate with software on running on a computer (e.g. Flash, Processing, MaxMSP).

Arduino is a cross-platoform program. You'll have to follow different instructions for your personal OS. Check on the Arduino site for the latest instructions. *http://arduino.cc/en/Guide/HomePage*

Linux Install

Windows Install

Mac Install

Once you have downloaded/unzipped the arduino IDE, you can Plug the Arduino to your PC via USB cable.

Blink led

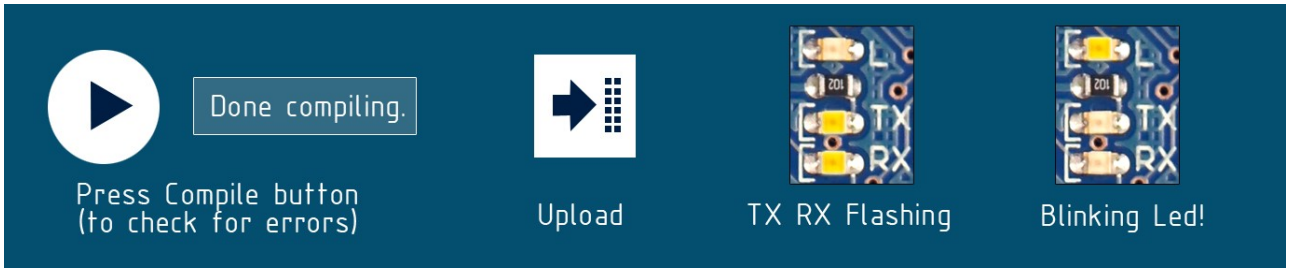
Now you're actually ready to "burn" your first program on the arduino board. To select "blink led", the physical translation of the well known programming "hello world", select

File>Sketchbook>
Arduino-0017>Examples>
Digital>Blink

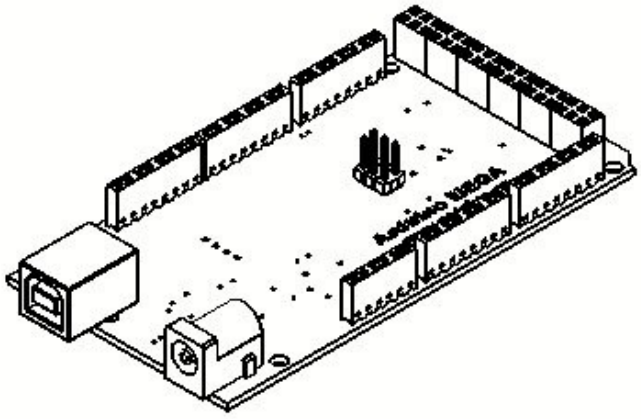
Once you have your skecth you'll see something very close to the screenshot on the right.

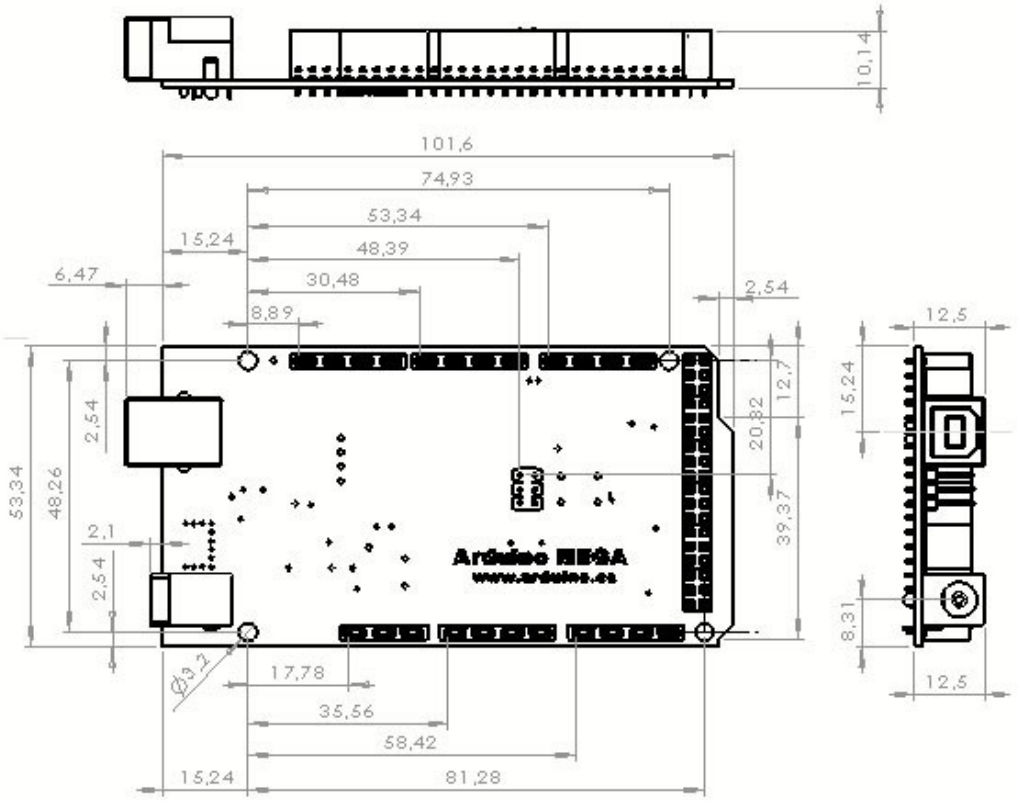
In **Tools>Board** select MEGA

Now you have to go to
Tools>SerialPort
and select the right serial port, the one arduino is attached to.



Dimensioned Drawing





Terms & Conditions

1. Warranties

1.1 The producer warrants that its products will conform to the Specifications. This warranty lasts for one (1) years from the date of the sale. The producer shall not be liable for any defects that are caused by neglect, misuse or mistreatment by the Customer, including improper installation or testing, or for any products that have been altered or modified in any way by a Customer. Moreover, The producer shall not be liable for any defects that result from Customer's design, specifications or instructions for such products. Testing and other quality control techniques are used to the extent the producer deems necessary.

1.2 If any products fail to conform to the warranty set forth above, the producer's sole liability shall be to replace such products. The producer's liability shall be limited to products that are determined by the producer not to conform to such warranty. If the producer elects to replace such products, the producer shall have a reasonable time to replacements. Replaced products shall be warranted for a new full warranty period.

1.3 EXCEPT AS SET FORTH ABOVE, PRODUCTS ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." THE PRODUCER DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING PRODUCTS, INCLUDING BUT NOT LIMITED TO, ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE

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Enviromental Policies

The producer of Arduino™ has joined the Impatto Zero® policy of LifeGate.it. For each Arduino board produced is created / looked after half squared Km of Costa Rica's forest's.

Appendix C

Amotec LCD

XIAMEN AMOTEC DISPLAY CO.,LTD

SPECIFICATIONS OF LCD MODULE

MODULE NO : ADM1602K-NSW-FBS/3.3V

DOC.REVISION: 00

	SIGNATURE	DATE
PREPARED BY (RD ENGINEER)	QIU	2008-10-29
CHECKED BY	Chen	2008-10-29
APPROVED BY	yf	2008-10-29

DOCUMENT REVISION HISTORY

VERSINO	DATE	DESCRIPTION	CHANGED BY
00	Oct-29-2008	First issue	

CONTENTS

1. Features

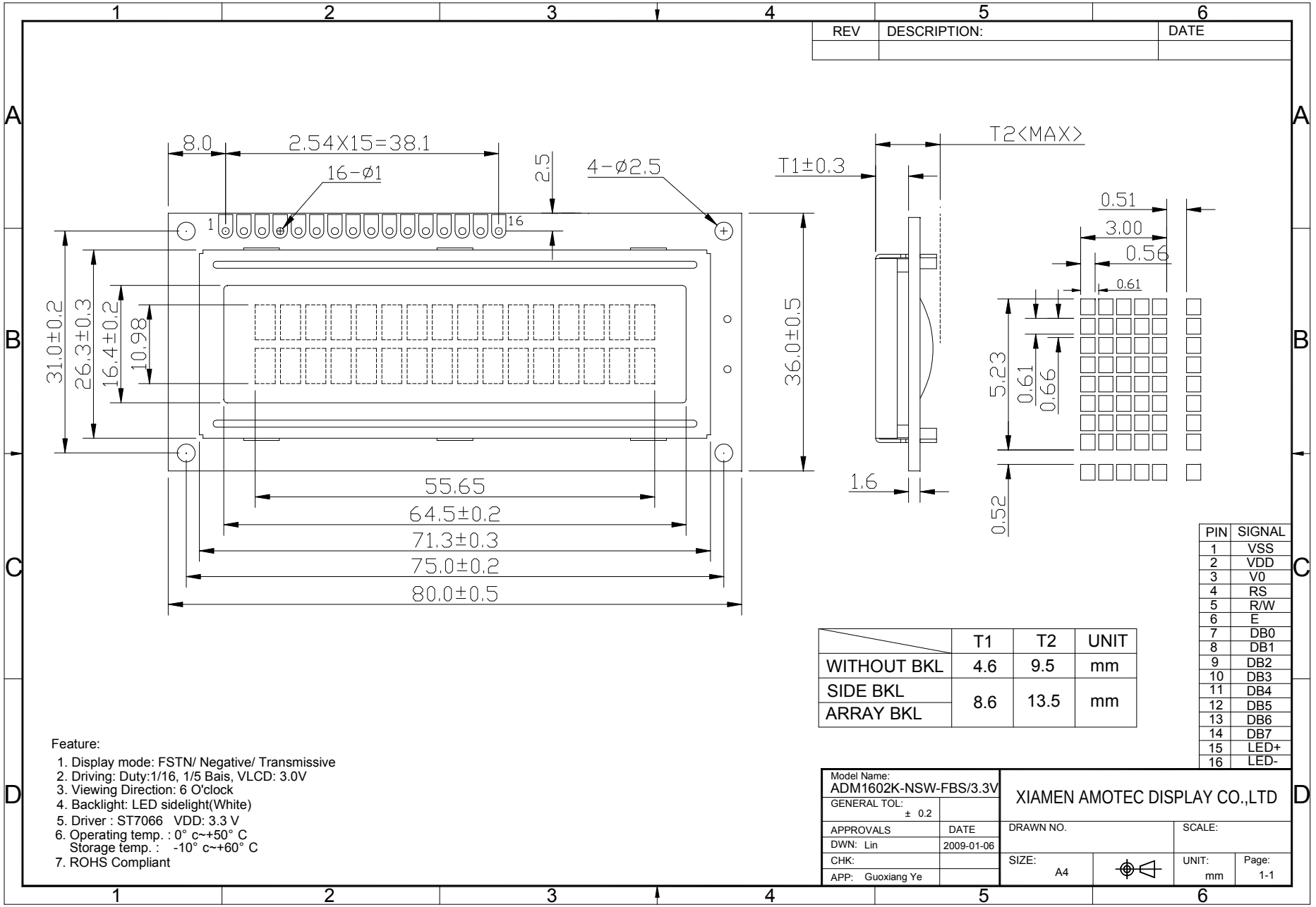
1. 5x8 dots with cursor
2. 16characters *2lines display
3. 4-bit or 8-bit MPU interfaces
4. Built-in controller (ST7066 or equivalent)
5. Display Mode & Backlight Variations
6. ROHS Compliant

LCD type	☐TN			
	☐FSTN	☑FSTN Negative		
	☐STN Yellow Green	☐STN Gray	☐STN Blue Negative	
View direction	☑6 O'clock	☐12 O'clock		
Rear Polarizer	☐Reflective	☐Transflective	☑Transmissive	
Backlight Type	☑LED	☐EL	☐Internal Power	☑3.3V Input
		☐CCFL	☑External Power	☐5.0V Input
Backlight Color	☑White	☐ Blue	☐ Amber	☐Yellow-Green
Temperature Range	☑Normal	☐Wide		☐Super Wide
DC to DC circuit	☐Build-in		☑Not Build-in	
Touch screen	☐With		☑Without	
Font type	☑English-Japanese	☐English-Europen	☐English-Russian	☐other

2. MECHANICAL SPECIFICATIONS

Module size	80.0mm(L)*36.0mm(W)* Max13.5(H)mm
Viewing area	64.5mm(L)*16.4mm(W)
Character size	3.00mm(L)*5.23mm(W)
Character pitch	3.51mm(L)*5.75mm(W)
Weight	Approx.

3. Outline dimension



	T1	T2	UNIT
WITHOUT BKL	4.6	9.5	mm
SIDE BKL / ARRAY BKL	8.6	13.5	mm

PIN	SIGNAL
1	VSS
2	VDD
3	V0
4	RS
5	R/W
6	E
7	DB0
8	DB1
9	DB2
10	DB3
11	DB4
12	DB5
13	DB6
14	DB7
15	LED+
16	LED-

Feature:

1. Display mode: FSTN/ Negative/ Transmissive
2. Driving: Duty:1/16, 1/5 Bais, VLCD: 3.0V
3. Viewing Direction: 6 O'clock
4. Backlight: LED sidelight(White)
5. Driver : ST7066 VDD: 3.3 V
6. Operating temp. : 0° c~+50° C
   Storage temp. : -10° c~+60° C
7. ROHS Compliant

Model Name:	ADM1602K-NSW-FBS/3.3V
GENERAL TOL: ± 0.2	
APPROVALS	DATE
DWN: Lin	2009-01-06
CHK:	
APP: Guoxiang Ye	

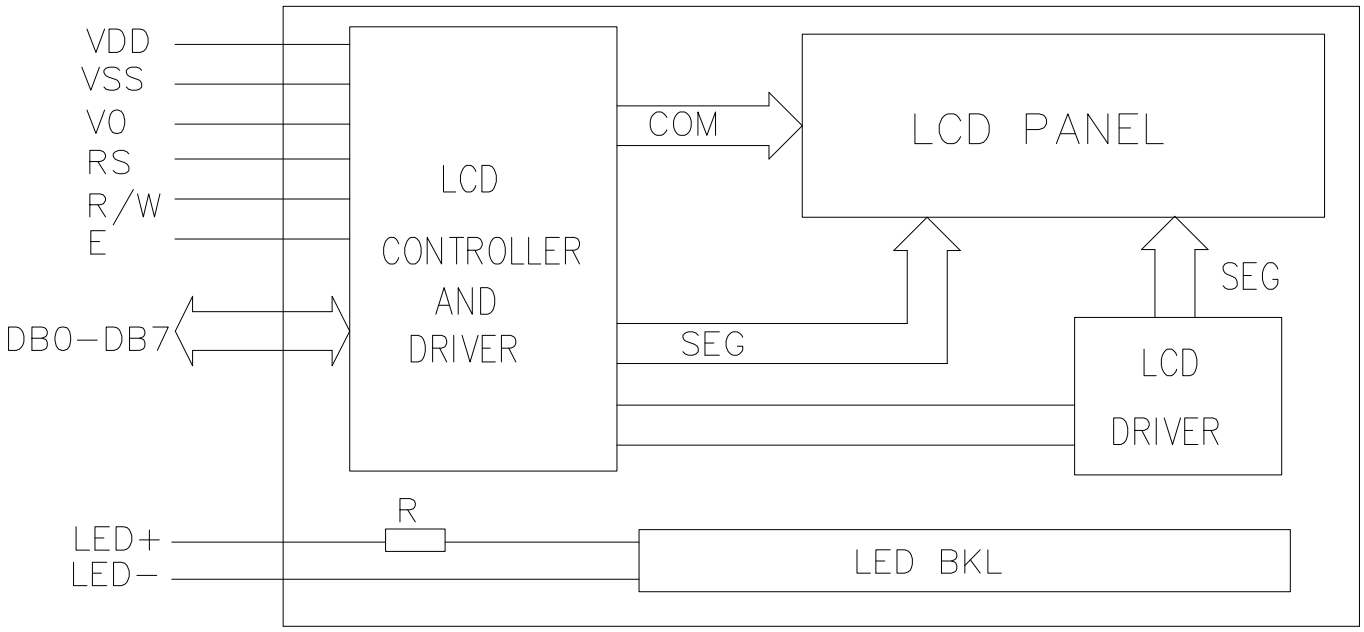
XIAMEN AMOTEC DISPLAY CO.,LTD

DRAWN NO.		SCALE:	
SIZE: A4		UNIT: mm	Page: 1-1

4. Absolute maximum ratings

Item	Symbol	Standard			Unit
Power voltage	V_{DD}-V_{SS}	0	-	7.0	V
Input voltage	V_{IN}	VSS	-	VDD	
Operating temperature range	V_{OP}	0	-	+50	℃
Storage temperature range	V_{ST}	-10	-	+60	

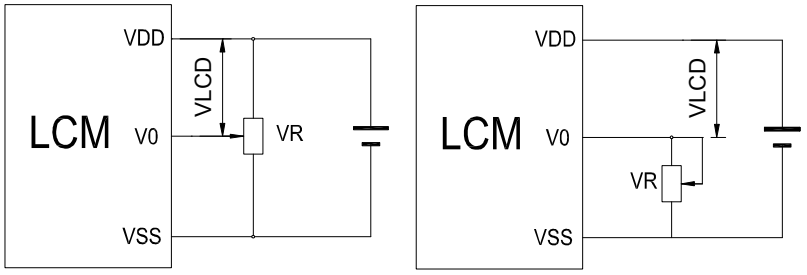
5. Block diagram



6. Interface pin description

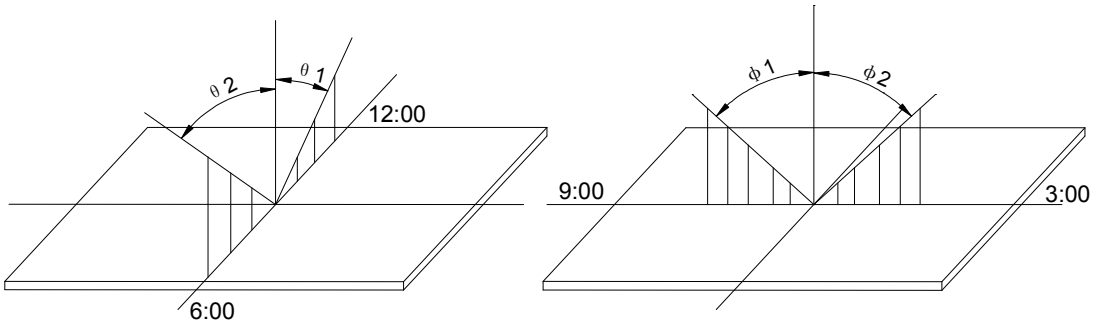
Pin no.	Symbol	External connection	Function
1	Vss	Power supply	Signal ground for LCM
2	V_{DD}		Power supply for logic for LCM
3	V_0		Contrast adjust
4	RS	MPU	Register select signal
5	R/W	MPU	Read/write select signal
6	E	MPU	Operation (data read/write) enable signal
7~10	DB0~DB3	MPU	Four low order bi-directional three-state data bus lines. Used for data transfer between the MPU and the LCM. These four are not used during 4-bit operation.
11~14	DB4~DB7	MPU	Four high order bi-directional three-state data bus lines. Used for data transfer between the MPU
15	LED+	LED BKL power supply	Power supply for BKL
16	LED-		Power supply for BKL

7. Contrast adjust



V_{DD}~V_0: LCD Driving voltage VR: 10k~20k

8. Optical characteristics



STN type display module (Ta=25℃, VDD=3.3V)

Item	Symbol	Condition	Min.	Typ.	Max.	Unit
Viewing angle	θ 1	$C_r \geqslant 3$		20		deg
	θ 2			40		
	Φ 1			35		
	Φ 2			35		
Contrast ratio	C_r		-	10	-	-
Response time (rise)	T_r	-	-	200	250	ms
Response time (fall)	T_r	-	-	300	350	

9. Electrical characteristics

DC characteristics

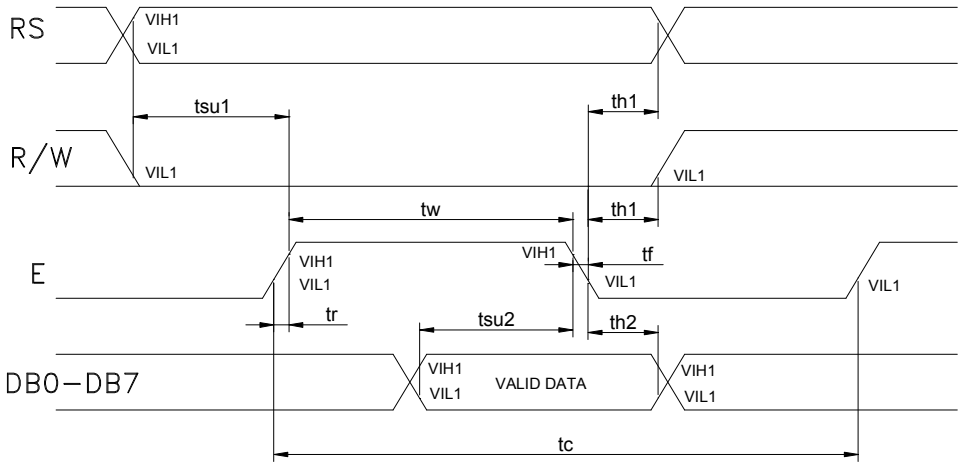
Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Supply voltage for LCD	V_{DD}-V_0	Ta =25℃	-	3.0	-	V
Input voltage	V_{DD}		3.1	3.3	3.5	
Supply current	I_{DD}	Ta=25℃, V_{DD}=3.3V	-	1.5	2.5	mA
Input leakage current	I_{LKG}		-	-	1.0	uA
“H” level input voltage	V_{IH}		2.2	-	V_{DD}	V
“L” level input voltage	V_{IL}	Twice initial value or less	0	-	0.6	
“H” level output voltage	V_{OH}	LOH=-0.25mA	2.4	-	-	
“L” level output voltage	V_{OL}	LOH=1.6mA	-	-	0.4	
Backlight supply voltage	V_F		-	3.0		
Backlight supply current	I_{LED}	V_{LED}=3.3 V R=25 Ω			16	mA

10. Timing Characteristics

Write cycle (Ta=25℃, VDD=3.3V)

Parameter	Symbol	Test pin	Min.	Typ.	Max.	Unit
Enable cycle time	t_c	E	500	-	-	ns
Enable pulse width	t_w		300	-	-	
Enable rise/fall time	t_r, t_f		-	-	25	
RS; R/W setup time	t_{su1}	RS; R/W	100	-	-	
RS; R/W address hold time	t_{h1}	RS; R/W	10	-	-	
Read data output delay	t_{su2}	DB0~DB7	60	-	-	
Read data hold time	t_{h2}		10	-	-	

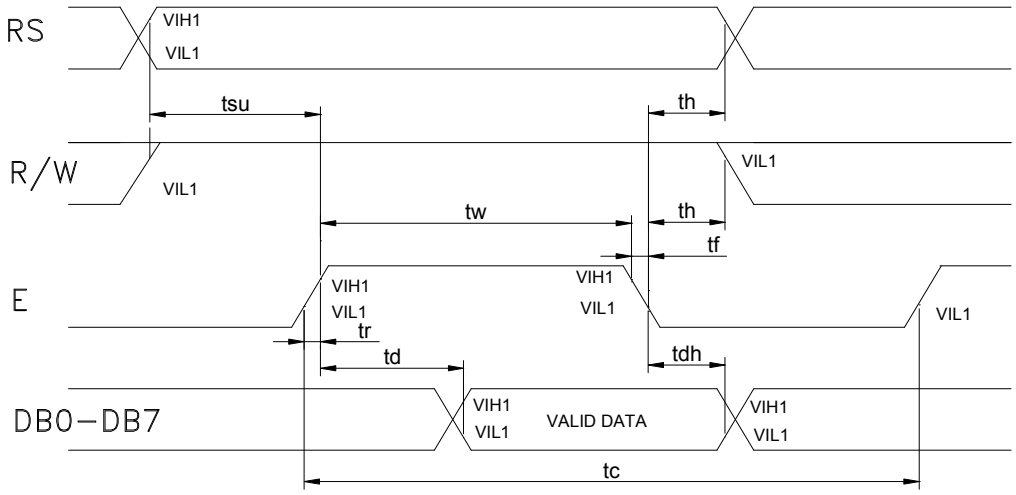
Write mode timing diagram



Read cycle (Ta=25℃, VDD=3.3V)

Parameter	Symbol	Test pin	Min.	Typ.	Max.	Unit
Enable cycle time	t_c	E	500	-	-	ns
Enable pulse width	t_w		300	-	-	
Enable rise/fall time	t_r, t_f		-	-	25	
RS; R/W setup time	t_{su}	RS; R/W	100	-	-	
RS; R/W address hold time	t_h	RS; R/W	10	-	-	
Read data output delay	t_d	DB0~DB7	60	-	90	
Read data hold time	t_{dh}		20	-	-	

Read mode timing diagram



11. FUNCTION DESCRIPTION

11.1 System Interface

This chip has all two kinds of interface type with MPU : 4-bit bus and 8-bit bus. 4-bit bus and 8-bit bus is selected by DL bit in the instruction register.

11.2 Busy Flag (BF)

When BF = “High”, it indicates that the internal operation is being processed. So during this time the next instruction cannot be accepted. BF can be read, when RS = Low and R/W = High (Read Instruction Operation), through DB7 port. Before executing the next instruction, be sure that BF is not high.

11.3 Address Counter (AC)

Address Counter (AC) stores DDRAM/CGRAM address, transferred from IR. After writing into (reading from) DDRAM/CGRAM, AC is automatically increased (decreased) by 1. When RS = “Low” and R/W = “High”, AC can be read through DB0 – DB6 ports.

11.4 Display Data RAM (DDRAM)

DDRAM stores display data of maximum 80 x 8 bits (80 characters). DDRAM address is set in the address counter (AC) as a hexadecimal number.

Display position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
DDRAM address	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F
DDRAM address	40	41	42	43	44	45	46	47	48	49	4A	4B	4C	4D	4E	4F

11.5 CGROM (Character Generator ROM)

CGROM has a 5 x 8 dots 204 characters pattern and a 5 x 10 dots 32 characters pattern. CGROM has 204 character patterns of 5 x 8 dots.

11.6 CGRAM (Character Generator RAM)

CGRAM has up to 5 ． 8 dot, 8 characters. By writing font data to CGRAM, user defined characters can be used.

Character Code (DDRAM Data)									CGRAM Address						Character Patterns (CGRAM Data)							
b8	b7	b6	b5	b4	b3	b2	b1	b0	b5	b4	b3	b2	b1	b0	b7	b6	b5	b4	b3	b2	b1	b0
0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	-	-	-	1	1	1	1	1
						0	0	0				0	0	1				0	0	1	0	0
						0	0	0				0	1	0				0	0	1	0	0
						0	0	0				0	1	1				0	0	1	0	0
						0	0	0				1	0	0				0	0	1	0	0
						0	0	0				1	0	1				0	0	1	0	0
						0	0	0				1	1	0				0	0	1	0	0
						0	0	0				1	1	1				0	0	0	0	0
0	0	0	0	0	-	0	0	1	0	0	1	0	0	0	-	-	-	1	1	1	1	0
						0	0	1				0	0	1				1	0	0	0	1
						0	0	1				0	1	0				1	0	0	0	1
						0	0	1				0	1	1				1	1	1	1	0
						0	0	1				1	0	0				1	0	1	0	0
						0	0	1				1	0	1				1	0	0	1	0
						0	0	1				1	1	0				1	0	0	0	1
						0	0	1				1	1	1				0	0	0	0	0

Relationship between CGRAM Addresses, Character Codes (DDRAM) and Character patterns (CGRAM Data)

Notes:

1. Character code bits 0 to 2 correspond to CGRAM address bits 3 to 5 (3 bits: 8 types).
2. CGRAM address bits 0 to 2 designate the character pattern line position. The 8th line is the cursor position

and its display is formed by a logical OR with the cursor. Maintain the 8th line data, corresponding to the cursor display position, at 0 as the cursor display. If the 8th line data is 1, 1 bit will light up the 8th line regardless of the cursor presence.
3. Character pattern row positions correspond to CGRAM data bits 0 to 4 (bit 4 being at the left).
4. As shown Table, CGRAM character patterns are selected when character code bits 4 to 7 are all 0. However, since character code bit 3 has no effect, the R display example above can be selected by either character code 00H or 08H.
5. 1 for CGRAM data corresponds to display selection and 0 to non-selection.
"-": Indicates no effect.

11.7 Cursor/Blink Control Circuit
It controls cursor/blink ON/OFF at cursor position.

11.8 Outline
To overcome the speed difference between the internal clock of ST7066 and the MPU clock, ST7066 performs internal operations by storing control in formations to IR or DR. The internal operation is determined according to the signal from MPU, composed of read/write and data bus (Refer to Table7).
Instructions can be divided largely into four groups:

1) ST7066 function set instructions (set display methods, set data length, etc.)
2) Address set instructions to internal RAM
3) Data transfer instructions with internal RAM
4) Others

The address of the internal RAM is automatically increased or decreased by 1.

Note: during internal operation, busy flag (DB7) is read "High".
Busy flag check must be preceded by the next instruction.

11.9 Instruction Table

Instruction	Instruction code										Description	Execution time (fosc= 270 KHZ
	RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0		
Clear Display	0	0	0	0	0	0	0	0	0	1	Write “20H” to DDRA and set DDRAM address to “00H” from AC	1.53ms
Return Home	0	0	0	0	0	0	0	0	1	-	Set DDRAM address to “00H” From AC and return cursor to Its original position if shifted. The contents of DDRAM are not changed.	1.53ms
Entry mode Set	0	0	0	0	0	0	0	1	I/D	SH	Assign cursor moving direction And blinking of entire display	39us
Display ON/ OFF control	0	0	0	0	0	0	1	D	C	B	Set display (D), cursor (C), and Blinking of cursor (B) on/off Control bit.	
Cursor or Display shift	0	0	0	0	0	1	S/C	R/L	-	-	Set cursor moving and display Shift control bit, and the Direction, without changing of DDRAM data.	39us
Function set	0	0	0	0	1	DL	N	F	-	-	Set interface data length (DL: 8- Bit/4-bit), numbers of display Line (N: =2-line/1-line) and, Display font type (F: 5x11/5x8)	39us
Set CGRAM Address	0	0	0	1	AC5	AC4	AC3	AC2	AC1	AC0	Set CGRAM address in address Counter.	39us
Set DDRAM Address	0	0	1	AC6	AC5	AC4	AC3	AC2	AC1	AC0	Set DDRAM address in address Counter.	39us
Read busy Flag and Address	0	1	BF	AC6	AC5	AC4	AC3	AC2	AC1	AC0	Whether during internal Operation or not can be known By reading BF. The contents of Address counter can also be read.	0us
Write data to Address	1	0	D7	D6	D5	D4	D3	D2	D1	D0	Write data into internal RAM (DDRAM/CGRAM).	43us
Read data From RAM	1	1	D7	D6	D5	D4	D3	D2	D1	D0	Read data from internal RAM (DDRAM/CGRAM).	43us

NOTE:

When an MPU program with checking the busy flag (DB7) is made, it must be necessary 1/2fosc is necessary for executing the next instruction by the falling edge of the “E” signal after the busy flag (DB7) goes to “Low”.

11.3Contents

1) Clear display

RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	0	0	0	0	0	0	0	0	1

Clear all the display data by writing “20H” (space code) to all DDRAM address, and set DDRAM address to “00H” into AC (address counter).

Return cursor to the original status, namely, bring the cursor to the left edge on the fist line of the display.

Make the entry mode increment (I/D=“High”).

2) Return home

RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	0	0	0	0	0	0	0	1	-

Return home is cursor return home instruction.

Set DDRAM address to “00H” into the address counter.
Return cursor to its original site and return display to its original status, if shifted.
Contents of DDRAM does not change.

3) Entry mode set

RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	0	0	0	0	0	0	1	I/D	SH

Set the moving direction of cursor and display.

I/D: increment / decrement of DDRAM address (cursor or blink)
When I/D=“high”, cursor/blink moves to right and DDRAM address is increased by 1.
When I/D=“Low”, cursor/blink moves to left and DDRAM address is increased by 1.
*CGRAM operates the same way as DDRAM, when reading from or writing to CGRAM.

SH: shift of entire display
When DDRAM read (CGRAM read/write) operation or SH=“Low”, shifting of entire display is not performed. If SH =“High” and DDRAM write operation, shift of entire display is performed according to I/D value. (I/D=“high”. shift left, I/D=“Low”. Shift right).

4) Display ON/OFF control

RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	0	0	0	0	0	1	D	C	B

Control display/cursor/blink ON/OFF 1 bit register.

D: Display ON/OFF control bit
When D=“High”, entire display is turned on.
When D=“Low”, display is turned off, but display data remains in DDRAM.

C: cursor ON/OFF control bit
When D=“High”, cursor is turned on.
When D=“Low”, cursor is disappeared in current display, but I/D register preserves its data.

B: Cursor blink ON/OFF control bit
When B=“High”, cursor blink is on, which performs alternately between all the “High” data and display characters at the cursor position.
When B=“Low”, blink is off.

5) Cursor or display shift

RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	0	0	0	0	1	S/C	R/L	-	-

Shifting of right/left cursor position or display without writing or reading of display data.
This instruction is used to correct or search display data.
During 2-line mode display, cursor moves to the 2nd line after the 40th digit of the 1st line.
Note that display shift is performed simultaneously in all the lines.
When display data is shifted repeatedly, each line is shifted individually.
When display shift is performed, the contents of the address counter are not changed.

Shift patterns according to S/C and R/L bits

S/C	R/L	Operation
0	0	Shift cursor to the left, AC is decreased by 1
0	1	Shift cursor to the right, AC is increased by 1
1	0	Shift all the display to the left, cursor moves according to the display
1	1	Shift all the display to the right, cursor moves according to the display

6) Function set

RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	0	0	0	1	DL	N	F	-	-

DL: Interface data length control bit

When DL="High", it means 8-bit bus mode with MPU.
When DL="Low", it means 4-bit bus mode with MPU. Hence, DL is a signal to select 8-bit or 4-bit bus mode.
When 4-but bus mode, it needs to transfer 4-bit data twice.

N: Display line number control bit

When N="Low", 1-line display mode is set.
When N="High", 2-line display mode is set.

F: Display line number control bit

When F="Low", 5x8 dots format display mode is set.
When F="High", 5x11 dots format display mode.

7) Set CGRAM address

RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	0	0	1	AC5	AC4	AC3	AC2	AC1	AC0

Set CGRAM address to AC.
The instruction makes CGRAM data available from MPU.

8) Set DDRAM address

RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	0	1	AC6	AC5	AC4	AC3	AC2	AC1	AC0

Set DDRAM address to AC.
This instruction makes DDRAM data available form MPU.
When 1-line display mode (N=LOW), DDRAM address is form "00H" to "4FH".In 2-line display mode (N=High), DDRAM address in the 1st line form "00H" to "27H", and DDRAM address in the 2nd line is from "40H" to "67H".

9) Read busy flag & address

RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	1	BF	AC6	AC5	AC4	AC3	AC2	AC1	AC0

This instruction shows whether SPLC780D is in internal operation or not.
If the resultant BF is "High", internal operation is in progress and should wait BF is to be LOW, which by then the nest instruction can be performed. In this instruction you can also read the value of the address counter.

10) Write data to RAM

RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
1	0	D7	D6	D5	D4	D3	D2	D1	D0

Write binary 8-bit data to DDRAM/CGRAM.
The selection of RAM from DDRAM, and CGRAM, is set by the previous address set instruction (DDRAM address set, CGRAM address set).
RAM set instruction can also determine the AC direction to RAM.
After write operation. The address is automatically increased/decreased by 1, according to the entry mode.

11) Read data from RAM

RS	R/W	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
1	1	D7	D6	D5	D4	D3	D2	D1	D0

Read binary 8-bit data from DDRAM/CGRAM.

The selection of RAM is set by the previous address set instruction. If the address set instruction of RAM is not performed before this instruction, the data that has been read first is invalid, as the direction of AC is not yet determined. If RAM data is read several times without RAM address instructions set before, read operation, the correct RAM data can be obtained from the second. But the first data would be incorrect, as there is no time margin to transfer RAM data.

In case of DDRAM read operation, cursor shift instruction plays the same role as DDRAM address set

instruction, it also transfers RAM data to output data register.

After read operation, address counter is automatically increased/decreased by 1 according to the entry mode.

After CGRAM read operation, display shift may not be executed correctly.

NOTE: In case of RAM write operation, AC is increased/decreased by 1 as in read operation.

At this time, AC indicates next address position, but only the previous data can be read by the read instruction.

12.Standard character pattern

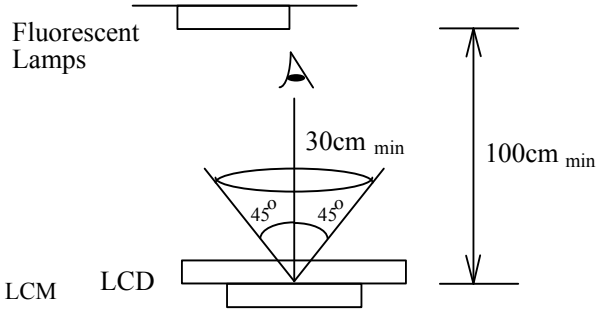
Upper 4bit / Lower 4bit	LLLL	LLLH	LLHL	LLHH	LHLL	LHLH	LHHL	LHHH	HLLL	HLLH	HLHL	HLHH	HHLL	HHLH	HHHL	HHHH
LLLL	CG RAM (1)															
LLLH	(2)															
LLHL	(3)															
LLHH	(4)															
LHLL	(5)															
LHLH	(6)															
LHHL	(7)															
LHHH	(8)															
HLLL	(1)															
HLLH	(2)															
HLHL	(3)															
HLHH	(4)															
HHLL	(5)															
HHLH	(6)															
HHHL	(7)															
HHHH	(8)															

13. QUALITY SPECIFICATIONS

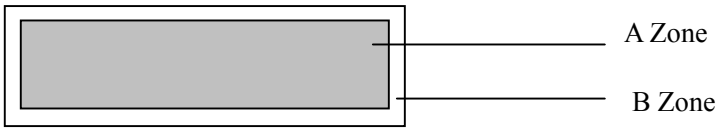
13.1 Standard of the product appearance test

Manner of appearance test: The inspection should be performed in using 20W x 2 fluorescent lamps. Distance between LCM and fluorescent lamps should be 100 cm or more. Distance between LCM and inspector eyes should be 30 cm or more.

Viewing direction for inspection is 45° from vertical against LCM.



Definition of zone:



A Zone: Active display area (minimum viewing area).
B Zone: Non-active display area (outside viewing area).

13.2 Specification of quality assurance

AQL inspection standard

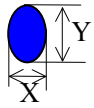
Sampling method: MIL-STD-105E, Level II, single sampling

Defect classification **(Note: * is not including)**

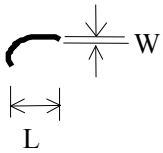
Classify	Item		Note	AQL
Major	Display state	Short or open circuit	1	0.65
		LC leakage		
		Flickering		
		No display		
		Wrong viewing direction		
		Contrast defect (dim, ghost)	2	
		Back-light	1,8	
	Non-display	Flat cable or pin reverse	10	
		Wrong or missing component	11	
Minor	Display state	Background color deviation	2	1.0
		Black spot and dust	3	
		Line defect, Scratch	4	
		Rainbow	5	
		Chip	6	
		Pin hole	7	
	Polarizer	Protruded	12	
		Bubble and foreign material	3	
	Soldering	Poor connection	9	
	Wire	Poor connection	10	
	TAB	Position, Bonding strength	13	

Note on defect classification

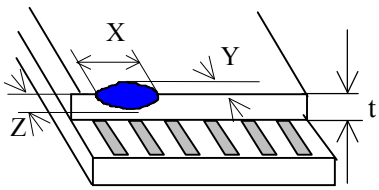
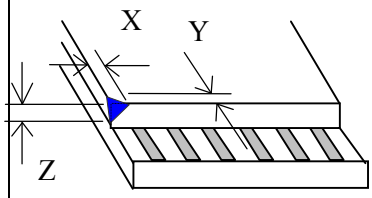
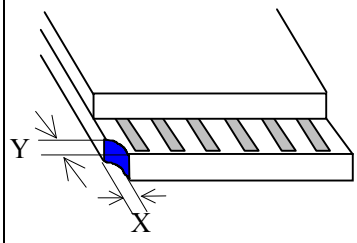
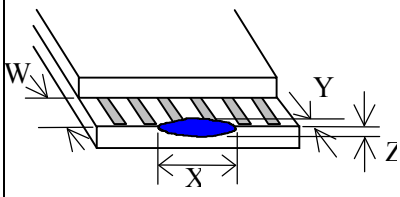
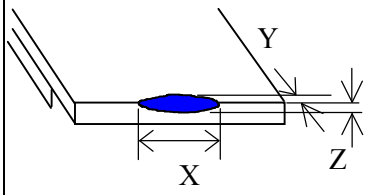
<table>
<tr><th>No.</th><th>Item</th><th>Criterion</th></tr>
<tr><td rowspan="6">1</td><td>Short or open circuit</td><td rowspan="6">Not allow</td></tr>
<tr><td>LC leakage</td></tr>
<tr><td>Flickering</td></tr>
<tr><td>No display</td></tr>
<tr><td>Wrong viewing direction</td></tr>
<tr><td>Wrong Back-light</td></tr>
<tr><td rowspan="2">2</td><td>Contrast defect</td><td rowspan="2">Refer to approval sample</td></tr>
<tr><td>Background color deviation</td></tr>
<tr><td>3</td><td>Point defect,
Black spot, dust
(including Polarizer)

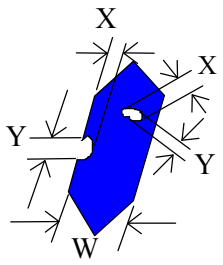
ϕ = (X+Y)/2</td><td> 

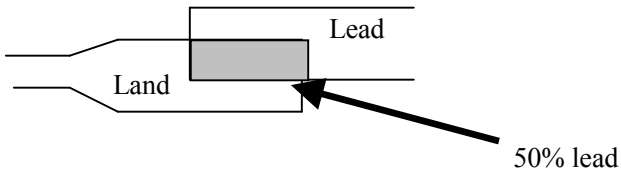
<table>
<tr><th>Point Size</th><th>Acceptable Qty.</th></tr>
<tr><td>ϕ≤0.10</td><td>Disregard</td></tr>
<tr><td>0.10<ϕ≤0.20</td><td>3</td></tr>
<tr><td>0.20<ϕ≤0.25</td><td>2</td></tr>
<tr><td>0.25<ϕ≤0.30</td><td>1</td></tr>
<tr><td>ϕ>0.30</td><td>0</td></tr>
</table>
Unit：mm</td></tr>
<tr><td>4</td><td>Line defect,

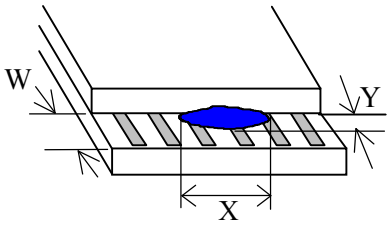
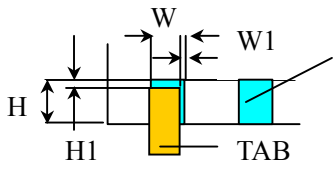
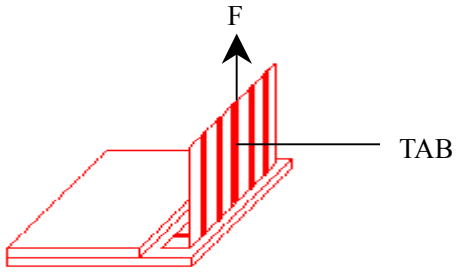
Scratch</td><td> 

<table>
<tr><th colspan="2">Line</th><th>Acceptable Qty.</th></tr>
<tr><td>L</td><td>W</td><td></td></tr>
<tr><td>---</td><td>0.015≥W</td><td>Disregard</td></tr>
<tr><td>3.0≥L</td><td>0.03≥W</td><td rowspan="2">2</td></tr>
<tr><td>2.0≥L</td><td>0.05≥W</td></tr>
<tr><td>1.0≥L</td><td>0.1＞W</td><td>1</td></tr>
<tr><td>---</td><td>0.05<W</td><td>Applied as point defect</td></tr>
</table>
Unit: mm</td></tr>
<tr><td>5</td><td>Rainbow</td><td>Not more than two color changes across the viewing area.</td></tr>
</table>

No	Item	Criterion
6	Chip Remark: X: Length direction Y: Short direction Z: Thickness direction t: Glass thickness W: Terminal Width	 Acceptable criterion X: ≤2; Y: 0.5mm; Z: ≤t/2  Acceptable criterion X: ≤2; Y: 0.5mm; Z: ≤t  Acceptable criterion X: ≤3; Y: ≤2; Z: ≤t shall not reach to ITO  Acceptable criterion X: Disregard; Y: ≤0.2; Z: ≤t  Acceptable criterion X: ≤5; Y: ≤2; Z: ≤t/3

<table>
<tr><th>No.</th><th>Item</th><th>Criterion</th></tr>
<tr><td>7</td><td>Segment
pattern
W = Segment width
ϕ = (X+Y)/2</td><td>(1) Pin hole
ϕ < 0.10mm is acceptable.
 

<table>
<tr><th>Point Size</th><th>Acceptable Qty</th></tr>
<tr><td>ϕ≤1/4W</td><td>Disregard</td></tr>
<tr><td>1/4W< ϕ≤1/2W</td><td>1</td></tr>
<tr><td>ϕ>1/2W</td><td>0</td></tr>
</table>
Unit: mm</td></tr>
<tr><td>8</td><td>Back-light</td><td>(1) The color of backlight should correspond its specification.
(2) Not allow flickering</td></tr>
<tr><td>9</td><td>Soldering</td><td>(1) Not allow heavy dirty and solder ball on PCB.
(The size of dirty refer to point and dust defect)
(2) Over 50% of lead should be solderedon Land.
 
</td></tr>
<tr><td>10</td><td>Wire</td><td>(1) Copper wire should not be rusted
(2) Not allow crack on copper wire connection.
(3) Not allow reversing the position of the flat cable.
(4) Not allow exposed copper wire inside the flat cable.</td></tr>
<tr><td>11*</td><td>PCB</td><td>(1) Not allow screw rust or damage.
(2) Not allow missing or wrong putting of component.</td></tr>
</table>

No	Item	Criterion
12	Protruded W: Terminal Width	 Acceptable criteria: Y ≤ 0.4
13	TAB	1. Position  W1≤1/3W H1≤1/3H 2 TAB bonding strength test  P (=F/TAB bonding width) ≥650gf/cm ,(speed rate: 1mm/min) 5pcs per SOA (shipment)
14	Total no. of acceptable Defect	A. Zone Maximum 2 minor non-conformities per one unit. Defect distance: each point to be separated over 10mm B. Zone It is acceptable when it is no trouble for quality and assembly in customer's end product.

13.3 Reliability of LCM

Reliability test condition:

Item	Condition	Time (hrs)	Assessment
High temp. Storage	80°C	48	No abnormalities in functions and appearance
High temp. Operating	70°C	48	
Low temp. Storage	-30°C	48	
Low temp. Operating	-20°C	48	
Humidity	40°C/ 90%RH	48	
Temp. Cycle	0°C ← 25°C→ 50°C (30 min ← 5 min → 30min)	10cycles	

Recovery time should be 24 hours minimum. Moreover, functions, performance and appearance shall be free from remarkable deterioration within 50,000 hours under ordinary operating and storage conditions room temperature (20±8°C), normal humidity (below 65% RH), and in the area not exposed to direct sun light.

13.4 Precaution for using LCD/LCM

LCD/LCM is assembled and adjusted with a high degree of precision. Do not attempt to make any alteration or modification. The followings should be noted.

General Precautions:

1. LCD panel is made of glass. Avoid excessive mechanical shock or applying strong pressure onto the surface of display area.
2. The polarizer used on the display surface is easily scratched and damaged. Extreme care should be taken when handling. To clean dust or dirt off the display surface, wipe gently with cotton, or other soft material soaked with isoproply alcohol, ethyl alcohol or trichlorotriflorothane, do not use water, ketone or aromatics and never scrub hard.
3. Do not tamper in any way with the tabs on the metal frame.
4. Do not make any modification on the PCB without consulting AMOTEC
5. When mounting a LCM, make sure that the PCB is not under any stress such as bending or twisting. Elastomer contacts are very delicate and missing pixels could result from slight dislocation of any of the elements.
6. Avoid pressing on the metal bezel, otherwise the elastomer connector could be deformed and lose contact, resulting in missing pixels and also cause rainbow on the display.
7. Be careful not to touch or swallow liquid crystal that might leak from a damaged cell. Any liquid crystal adheres to skin or clothes, wash it off immediately with soap and water.

Static Electricity Precautions:

1. CMOS LSI is used for the module circuit; therefore operators should be grounded whenever he/she comes into contact with the module.
2. Do not touch any of the conductive parts such as the LSI pads; the copper leads on the PCB and the interface terminals with any parts of the human body.

3. Do not touch the connection terminals of the display with bare hand; it will cause disconnection or defective insulation of terminals.
4. The modules should be kept in anti-static bags or other containers resistant to static for storage.
5. Only properly grounded soldering irons should be used.
6. If an electric screwdriver is used, it should be grounded and shielded to prevent sparks.
7. The normal static prevention measures should be observed for work clothes and working benches.
8. Since dry air is inductive to static, a relative humidity of 50-60% is recommended.

Soldering Precautions:

1. Soldering should be performed only on the I/O terminals.
2. Use soldering irons with proper grounding and no leakage.
3. Soldering temperature: 280°C±10°C
4. Soldering time: 3 to 4 second.
5. Use eutectic solder with resin flux filling.
6. If flux is used, the LCD surface should be protected to avoid spattering flux.
7. Flux residue should be removed.

Operation Precautions:

1. The viewing angle can be adjusted by varying the LCD driving voltage Vo.
2. Since applied DC voltage causes electro-chemical reactions, which deteriorate the display, the applied pulse waveform should be a symmetric waveform such that no DC component remains. Be sure to use the specified operating voltage.
3. Driving voltage should be kept within specified range; excess voltage will shorten display life.
4. Response time increases with decrease in temperature.
5. Display color may be affected at temperatures above its operational range.
6. Keep the temperature within the specified range usage and storage. Excessive temperature and humidity could cause polarization degradation, polarizer peel-off or generate bubbles.
7. For long-term storage over 40 C is required, the relative humidity should be kept below 60%,and avoid direct sunlight.

Limited Warranty

AMOTEC LCDs and modules are not consumer products, but may be incorporated by AMOTEC 's customers into consumer products or components thereof, AMOTEC does not warrant that its LCDs and components are fit for any such particular purpose.

1. The liability of AMOTEC is limited to repair or replacement on the terms set forth below. AMOTEC will not be responsible for any subsequent or consequential events or injury or damage to any personnel or user including third party personnel and/or user. Unless otherwise agreed in writing between AMOTEC and the customer, AMOTEC will only replace or repair any of its LCD which is found defective electrically or visually when inspected in accordance with AMOTEC general LCD inspection standard . (Copies available on request)
2. No warranty can be granted if any of the precautions state in handling liquid crystal display above has been disregarded. Broken glass, scratches on polarizer mechanical damages as well as defects that are caused accelerated environment tests are excluded from warranty.
3. In returning the LCD/LCM, they must be properly packaged; there should be detailed description of the failures or defect.

Appendix D

LM2678

LM2678 SIMPLE SWITCHER® High Efficiency 5-A Step-Down Voltage Regulator

1 Features

- Efficiency Up to 92%
- Simple and Easy to Design Using Off-the-Shelf External Components
- 120-mΩ DMOS Output Switch
- 3.3-V, 5-V, and 12-V Fixed Output and Adjustable (1.2 V to 37 V) Versions
- 50-μA Standby Current When Switched OFF
- ±2% Maximum Output Tolerance Over Full Line and Load Conditions
- Wide Input Voltage Range: 8 V to 40 V
- 260-kHz Fixed Frequency Internal Oscillator
- −40 to 125°C Operating Junction Temperature Range
- Create a Custom Design Using the LM2678 With the WEBENCH® Power Designer

2 Applications

- Simple-to-Design, High Efficiency (>90%) Step-Down Switching Regulators
- Efficient System Preregulator for Linear Voltage Regulators
- Battery Chargers

3 Description

The LM2678 series of regulators are monolithic integrated circuits which provide all of the active functions for a step-down (buck) switching regulator capable of driving up to 5-A loads with excellent line and load regulation characteristics. High efficiency (>90%) is obtained through the use of a low ON-resistance DMOS power switch. The series consists of fixed output voltages of 3.3 V, 5 V, and 12 V and an adjustable output version.

The SIMPLE SWITCHER® concept provides for a complete design using a minimum number of external components. A high fixed frequency oscillator (260 kHz) allows the use of physically smaller sized components. A family of standard inductors for use with the LM2678 are available from several manufacturers to greatly simplify the design process.

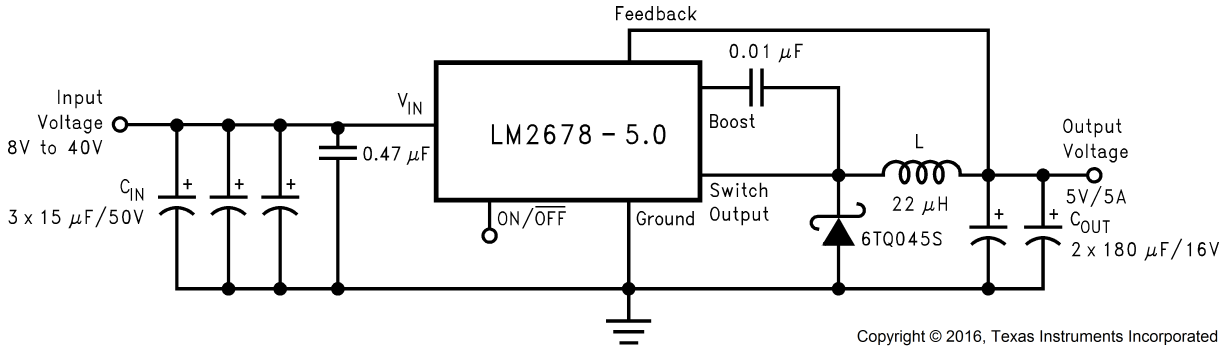
The LM2678 series also has built-in thermal shutdown, current limiting, and an ON/OFF control input that can power down the regulator to a low 50-μA quiescent current standby condition. The output voltage is ensured to a ±2% tolerance. The clock frequency is controlled to within a ±11% tolerance.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM2678	TO-263 (7)	10.10 mm × 8.89 mm
	TO-220 (7)	14.986 mm × 10.16 mm
	VSON (14)	6.00 mm × 5.00 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Typical Application



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4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision J (June 2016) to Revision K — **Page**

- Deleted RADJ = 5.6 kΩ ... 6
- Deleted and updated with new values for Min, Typ and Max ... 6
- Deleted and updated with new values for Min and Max ... 6
- Changed soft-start pin to ON/OFF pin ... 6
- Changed to 200 µA from 1.5 mA ... 6
- Changed typ and max values to 16 and 15 mA ... 6

Changes from Revision I (April 2013) to Revision J — **Page**

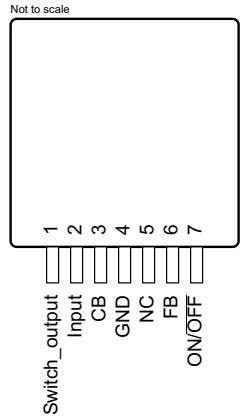
- Added *ESD Ratings* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section. ... 1
- Removed all references to Computer Design Software ***LM267X Made Simple*** (Version 6.0) ... 1

Changes from Revision H (April 2013) to Revision I — **Page**

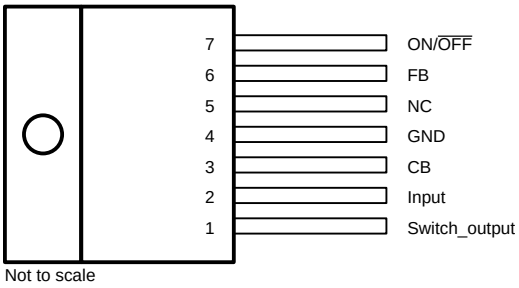
- Changed layout of National Data Sheet to TI format ... 29

5 Pin Configuration and Functions

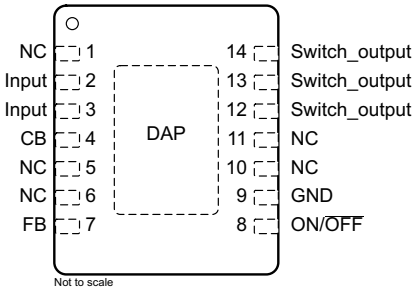
KTW Package
7-Pin TO-263
Top View



NDZ Package
7-Pin TO-220
Top View



NHM Package
14-Pin VSON
Top View



DAP connect to pin 9

Pin Functions

PIN			I/O	DESCRIPTION
NAME	TO-263, TO-220	VSON		
Switch output	1	12, 13, 14	O	Source pin of the internal high-side FET. This is a switching node. Attached this pin to an inductor and the cathode of the external diode.
Input	2	2, 3	I	Supply input pin to collector pin of high-side FET. Connect to power supply and input bypass capacitors C_{IN}. Path from V_{IN} pin to high frequency bypass C_{IN} and GND must be as short as possible.
CB	3	4	I	Boot-strap capacitor connection for high-side driver. Connect a high-quality 100-nF capacitor from CB to VSW Pin.
GND	4	9	—	Power ground pins. Connect to system ground. Ground pins of C_{IN} and C_{OUT}. Path to C_{IN} must be as short as possible.
FB	6	7	I	Feedback sense input pin. Connect to the midpoint of feedback divider to set V_{OUT} for ADJ version or connect this pin directly to the output capacitor for a fixed output version.
ON/$\overline{\text{OFF}}$	7	8	I	Enable input to the voltage regulator. High = ON and low = OFF. Pull this pin high or float to enable the regulator.
NC	5	1, 5, 6, 10, 11	—	No connect pins.

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)(2)

		MIN	MAX	UNIT
Input supply voltage			45	V
Soft-start pin voltage		–0.1	6	V
Switch voltage to ground(3)		–1	V_{IN}	V
Boost pin voltage			V_{SW} + 8	V
Feedback pin voltage		–0.3	14	V
Power dissipation		Internally limited		
Soldering temperature	Wave (4 s)		260	°C
	Infrared (10 s)		240	
	Vapor phase (75 s)		219	
Storage temperature, T_{stg}		–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/Distributors for availability and specifications.
(3) The absolute maximum specification of the *Switch Voltage to Ground* applies to DC voltage. An extended negative voltage limit of –10 V applies to a pulse of up to 20 ns, –6 V of 60 ns and –3 V of up to 100 ns.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)(2)	±2000	V

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) ESD was applied using the human-body model, a 100-pF capacitor discharged through a 1.5-kΩ resistor into each pin.

6.3 Recommended Operating Conditions

	MIN	MAX	UNIT
Supply voltage	8	40	V
Junction temperature, T_J	–40	125	°C

6.4 Thermal Information

THERMAL METRIC[1]			LM2678 NDZ (TO-220) 7 PINS	LM2678 KTW (TO-263) 7 PINS	LM2678 NHM (VSON) 14 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	See [2]	65	—	—	°C/W
		See [3]	45	—	—	
		See [4]	—	56	—	
		See [5]	—	35	—	
		See [6]	—	26	—	
		See [7]	—	—	55	
		See [8]	—	—	29	
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance		2	2	—	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report.
(2) Junction to ambient thermal resistance (no external heat sink) for the 7-lead TO-220 package mounted vertically, with ½ inch leads in a socket, or on a PCB with minimum copper area.
(3) Junction to ambient thermal resistance (no external heat sink) for the 7-lead TO-220 package mounted vertically, with ½ inch leads soldered to a PCB containing approximately 4 square inches of (1 oz.) copper area surrounding the leads.
(4) Junction to ambient thermal resistance for the 7-lead DDPAK mounted horizontally against a PCB area of 0.136 square inches (the same size as the DDPAK package) of 1 oz. (0.0014 in. thick) copper.
(5) Junction to ambient thermal resistance for the 7-lead DDPAK mounted horizontally against a PCB area of 0.4896 square inches (3.6 times the area of the DDPAK package) of 1 oz. (0.0014 in. thick) copper.
(6) Junction to ambient thermal resistance for the 7-lead DDPAK mounted horizontally against a PCB copper area of 1.0064 square inches (7.4 times the area of the DDPAK 3 package) of 1 oz. (0.0014 in. thick) copper. Additional copper area reduces thermal resistance further.
(7) Junction to ambient thermal resistance for the 14-lead VSON mounted on a PCB copper area equal to the die attach paddle.
(8) Junction to ambient thermal resistance for the 14-lead VSON mounted on a PCB copper area using 12 vias to a second layer of copper equal to die attach paddle. Additional copper area will reduce thermal resistance further. For layout recommendations, see *AN-1187 Leadless Leadfram Package (LLP)*.

6.5 Electrical Characteristics – 3.3 V

Specifications apply for $T_A = T_J = 25°C$ and $R_{ADJ} = 5.6\ k\Omega$ (unless otherwise noted).

PARAMETER		TEST CONDITIONS		MIN[1]	TYP[2]	MAX[1]	UNIT
V_{OUT}	Output voltage	V_{IN} = 8 V to 40 V, 100 mA ≤ I_{OUT} ≤ 5 A	T_J = 25°C	3.234	3.3	3.366	V
			T_J = –40°C to 125°C	3.201		3.399	
η	Efficiency	V_{IN} = 12 V, I_{LOAD} = 5 A			82%		

(1) All room temperature limits are 100% tested during production with $T_A = T_J = 25°C$. All limits at temperature extremes are specified through correlation using standard Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).
(2) Typical values are determined with $T_A = T_J = 25°C$ and represent the most likely norm.

6.6 Electrical Characteristics – 5 V

Specifications apply for $T_A = T_J = 25°C$ and $R_{ADJ} = 5.6\ k\Omega$ (unless otherwise noted).

PARAMETER		TEST CONDITIONS		MIN[1]	TYP[2]	MAX[1]	UNIT
V_{OUT}	Output voltage	V_{IN} = 8 V to 40 V, 100 mA ≤ I_{OUT} ≤ 5 A	T_J = 25°C	4.9	5	5.1	V
			T_J = –40°C to 125°C	4.85		5.15	
η	Efficiency	V_{IN} = 12 V, I_{LOAD} = 5 A			84%		

(1) All room temperature limits are 100% tested during production with $T_A = T_J = 25°C$. All limits at temperature extremes are specified through correlation using standard Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).
(2) Typical values are determined with $T_A = T_J = 25°C$ and represent the most likely norm.

6.7 Electrical Characteristics – 12 V

Specifications apply for $T_A = T_J = 25°C$ and $R_{ADJ} = 5.6\ k\Omega$ (unless otherwise noted).

PARAMETER		TEST CONDITIONS		MIN(1)	TYP(2)	MAX(1)	UNIT
V_{OUT}	Output voltage	V_{IN} = 15 V to 40 V, 100 mA ≤ I_{OUT} ≤ 5 A	T_J = 25°C	11.76	12	12.24	V
			T_J = –40°C to 125°C	11.64		12.36	
η	Efficiency	V_{IN} = 24 V, I_{LOAD} = 5 A			92%		

(1) All room temperature limits are 100% tested during production with $T_A = T_J = 25°C$. All limits at temperature extremes are specified through correlation using standard Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).
(2) Typical values are determined with $T_A = T_J = 25°C$ and represent the most likely norm.

6.8 Electrical Characteristics – Adjustable

Specifications apply for $T_A = T_J = 25°C$ and $R_{ADJ} = 5.6\ k\Omega$ (unless otherwise noted).

PARAMETER		TEST CONDITIONS		MIN(1)	TYP(2)	MAX(1)	UNIT
V_{FB}	Feedback voltage	V_{IN} = 8 V to 40 V, 100 mA ≤ I_{OUT} ≤ 5 A, V_{OUT} programmed for 5 V	T_J = 25°C	1.186	1.21	1.234	V
			T_J = –40°C to 125°C	1.174		1.246	
η	Efficiency	V_{IN} = 12 V, I_{LOAD} = 5 A			84%		

(1) All room temperature limits are 100% tested during production with $T_A = T_J = 25°C$. All limits at temperature extremes are specified through correlation using standard Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).
(2) Typical values are determined with $T_A = T_J = 25°C$ and represent the most likely norm.

6.9 Electrical Characteristics – All Output Voltage Versions

Specifications are for $T_A = T_J = 25°C$, V_{IN} = 12 V for the 3.3-V, 5-V, and adjustable versions, and V_{IN} = 24 V for the 12-V version (unless otherwise noted).

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
I_Q	Quiescent current	$V_{FEEDBACK}$ = 8 V for 3.3-V, 5-V, and adjustable versions, $V_{FEEDBACK}$ = 15 V for 12-V version			4.2	6	mA
I_{STBY}	Standby quiescent current	ON/$\overline{OFF}$ pin = 0 V	T_J = 25°C		50	100	µA
			T_J = –40°C to 125°C			150	
I_{CL}	Current limit		T_J = 25°C	6.1	7	8.3	A
			T_J = –40°C to 125°C	5.75		8.75	
I_L	Output leakage current	V_{IN} = 40 V, ON/$\overline{OFF}$ pin = 0 V	V_{SWITCH} = 0 V			200	µA
			V_{SWITCH} = –1 V		16	15	mA
$R_{DS(ON)}$	Switch ON-Resistance	I_{SWITCH} = 5 A	T_J = 25°C		0.12	0.14	Ω
			T_J = –40°C to 125°C			0.225	
f_O	Oscillator frequency	Measured at switch pin	T_J = 25°C		260		kHz
			T_J = –40°C to 125°C	225		280	
D	Duty cycle	Maximum duty cycle			91%		
		Minimum duty cycle			0%		
I_{BIAS}	Feedback bias current	$V_{FEEDBACK}$ = 1.3 V (adjustable version only)			85		nA
$V_{ON/OFF}$	ON/OFF threshold voltage	T_J = 25°C			1.4		V
		T_J = –40°C to 125°C		0.8		2	
$I_{ON/OFF}$	ON/OFF input current	ON/OFF input = 0 V	T_J = 25°C		20		µA
			T_J = –40°C to 125°C			45	

6.10 Typical Characteristics

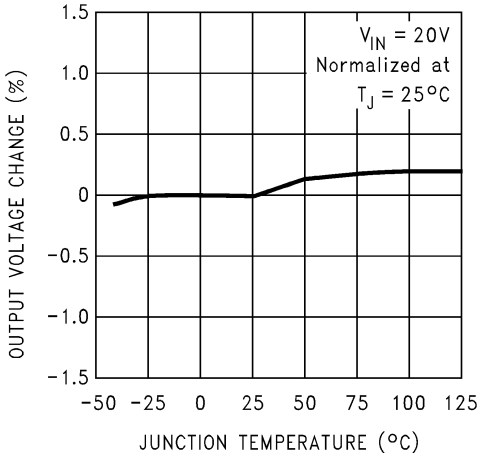


Figure 1. Normalized Output Voltage

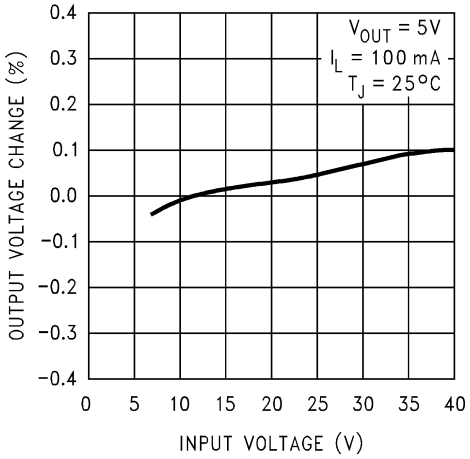


Figure 2. Line Regulation

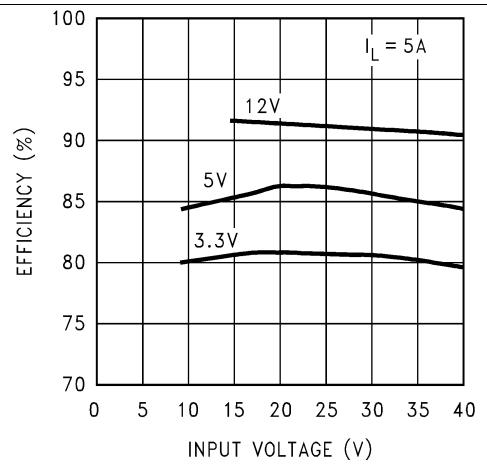


Figure 3. Efficiency vs Input Voltage

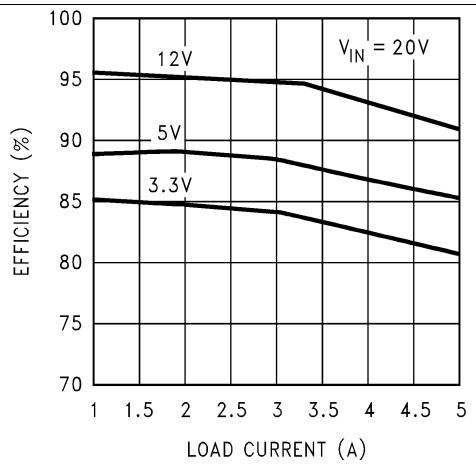


Figure 4. Efficiency vs I_{LOAD}

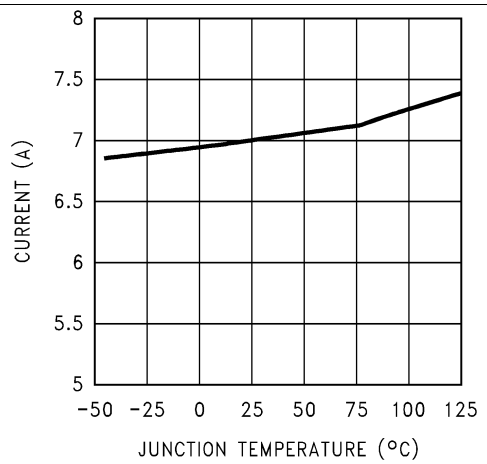


Figure 5. Switch Current Limit

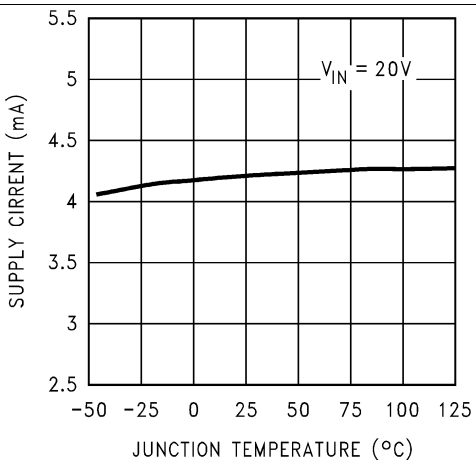


Figure 6. Operating Quiescent Current

Typical Characteristics (continued)

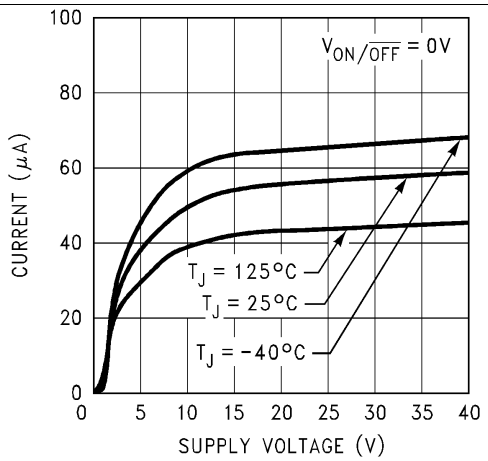


Figure 7. Standby Quiescent Current

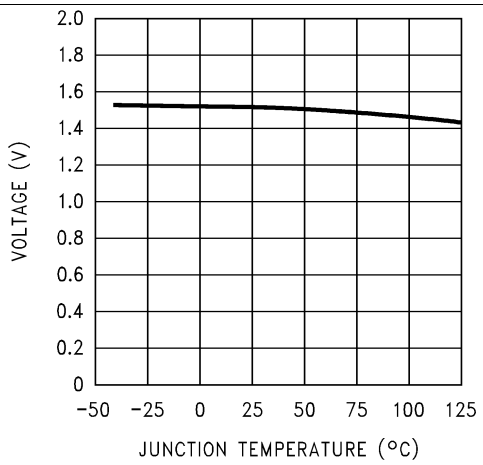


Figure 8. ON/OFF Threshold Voltage

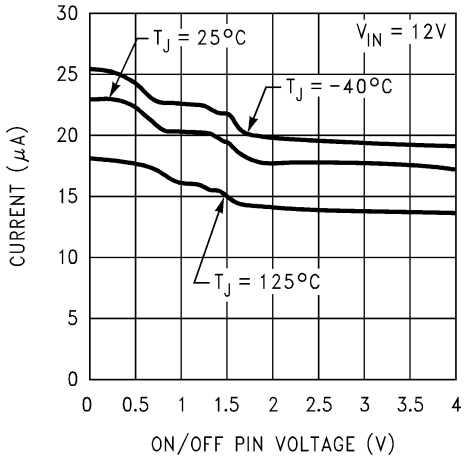


Figure 9. ON/OFF Pin Current (Sourcing)

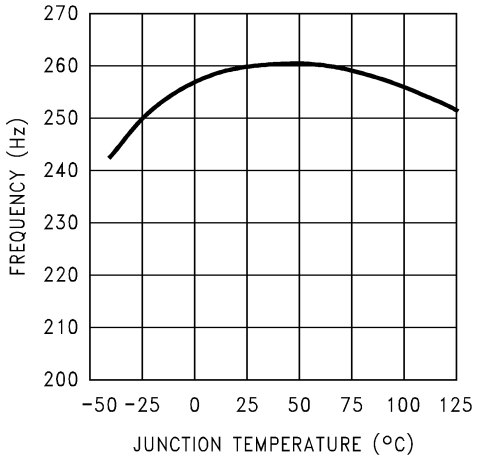


Figure 10. Switching Frequency

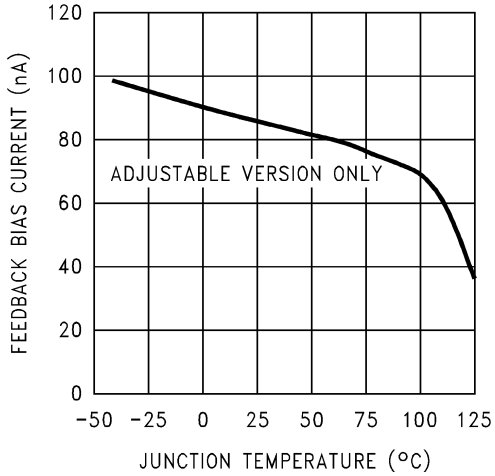
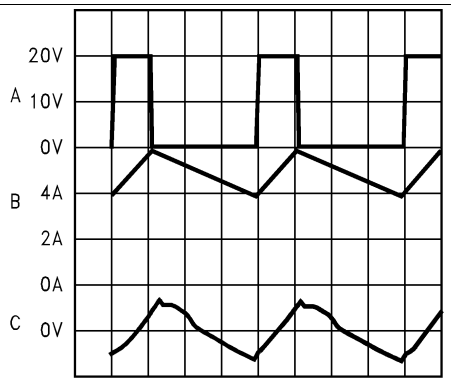


Figure 11. Feedback Pin Bias Current



Continuous Mode Switching Waveforms, V_{IN} = 20 V, V_{OUT} = 5 V, I_{LOAD} = 5 A, L = 10 µH, C_{OUT} = 400 µF, C_{OUT}ESR = 13 mΩ

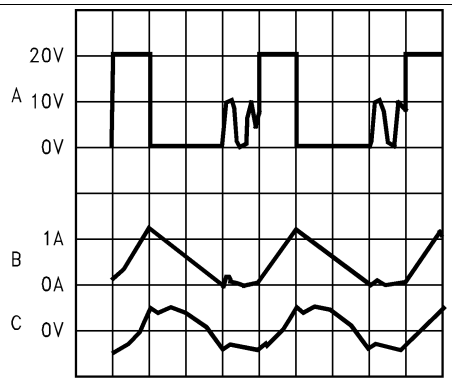
A. V_{SW} pin voltage = 10 V/div

B. Inductor current = 2 A/div

C. Output ripple voltage = 20 mV/div AC-coupled

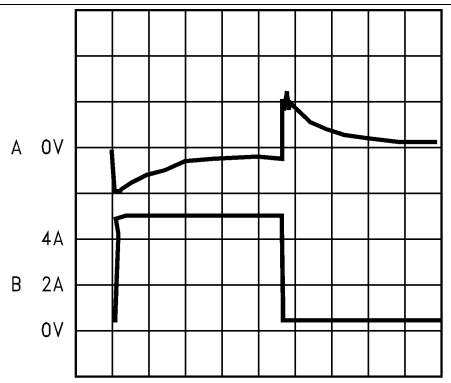
Figure 12. Horizontal Time Base: 1 µs/div

Typical Characteristics (continued)



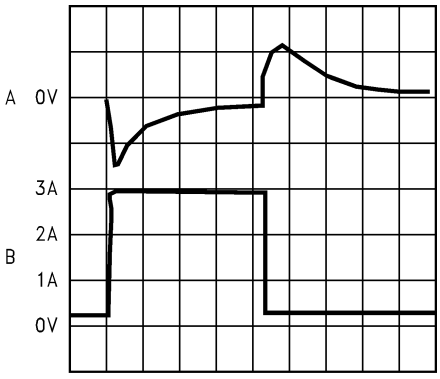
Discontinuous Mode Switching Waveforms, V_{IN} = 20 V, V_{OUT} = 5 V, I_{LOAD} = 500 mA, L = 10 μH, C_{OUT} = 400 μF, C_{OUT}ESR = 13 mΩ
A. V_{SW} pin voltage = 10 V/div
B. Inductor current = 1 A/div
C. Output ripple voltage = 20 mV/div AC-coupled

Figure 13. Horizontal Time Base: 1 μs/div



Load Transient Response for Continuous Mode, V_{IN} = 20 V, V_{OUT} = 5 V, L = 10 μH, C_{OUT} = 400 μF, C_{OUT}ESR = 13 mΩ
A. Output voltage = 100 mV/div, AC-coupled
B. Load current = 500-mA to 5-A load pulse

Figure 14. Horizontal Time Base: 100 μs/div



Load Transient Response for Discontinuous Mode, V_{IN} = 20 V, V_{OUT} = 5 V, vs L = 10 μH, C_{OUT} = 400 μF, C_{OUT}ESR = 13 mΩ
A. Output voltage = 100 mV/div, AC-coupled
B. Load current = 200-mA to 3-A load pulse

Figure 15. Horizontal Time Base: 200 μs/div

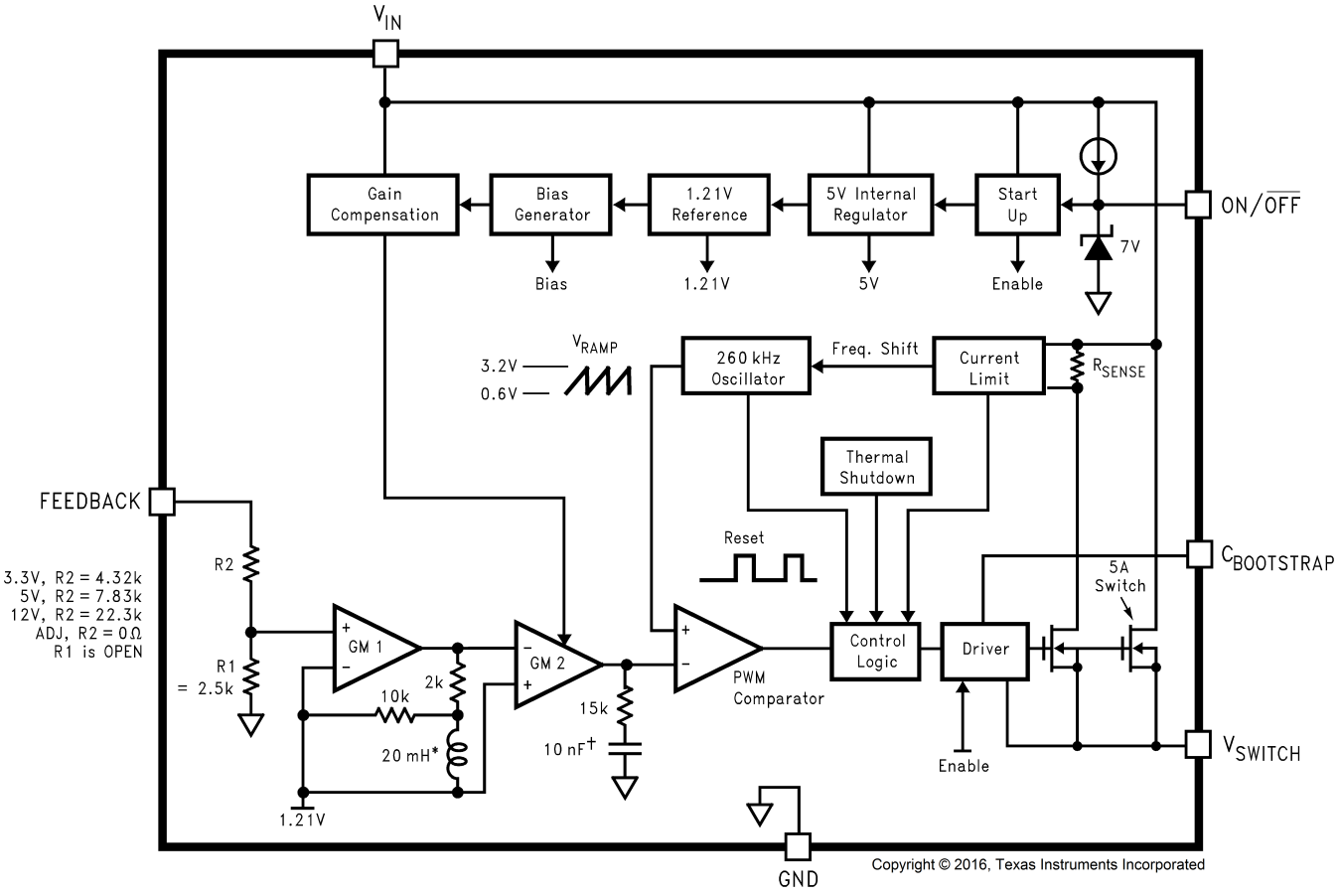
7 Detailed Description

7.1 Overview

The LM2678 provides all of the active functions required for a step-down (buck) switching regulator. The internal power switch is a DMOS power MOSFET to provide power supply designs with high current capability, up to 5 A, and highly efficient operation.

The LM2678 is part of the SIMPLE SWITCHER® family of power converters. The design support WEBENCH, can also be used to provide instant component selection, circuit performance calculations for evaluation, a bill of materials component list and a circuit schematic for LM2678.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 Switch Output

This is the output of a power MOSFET switch connected directly to the input voltage. The switch provides energy to an inductor, an output capacitor and the load circuitry under control of an internal pulse-width-modulator (PWM). The PWM controller is internally clocked by a fixed 260-kHz oscillator. In a standard step-down application the duty cycle (Time ON/Time OFF) of the power switch is proportional to the ratio of the power supply output voltage to the input voltage. The voltage on pin 1 switches between Vin (switch ON) and below ground by the voltage drop of the external Schottky diode (switch OFF).

Feature Description (continued)

7.3.2 Input

The input voltage for the power supply is connected to pin 2. In addition to providing energy to the load the input voltage also provides bias for the internal circuitry of the LM2678. For ensured performance the input voltage must be in the range of 8 V to 40 V. For best performance of the power supply the input pin must always be bypassed with an input capacitor located close to pin 2.

7.3.3 C Boost

A capacitor must be connected from pin 3 to the switch output, pin 1. This capacitor boosts the gate drive to the internal MOSFET above V_{IN} to fully turn it ON. This minimizes conduction losses in the power switch to maintain high efficiency. The recommended value for C Boost is 0.01 μF.

7.3.4 Ground

This is the ground reference connection for all components in the power supply. In fast-switching, high-current applications such as those implemented with the LM2678, TI recommends that a broad ground plane be used to minimize signal coupling throughout the circuit.

7.3.5 Feedback

This is the input to a two-stage high gain amplifier, which drives the PWM controller. It is necessary to connect pin 6 to the actual output of the power supply to set the DC output voltage. For the fixed output devices (3.3-V, 5-V and 12-V outputs), a direct wire connection to the output is all that is required as internal gain setting resistors are provided inside the LM2678. For the adjustable output version two external resistors are required to set the DC output voltage. For stable operation of the power supply it is important to prevent coupling of any inductor flux to the feedback input.

7.3.6 ON/OFF

This input provides an electrical ON/OFF control of the power supply. Connecting this pin to ground or to any voltage less than 0.8 V is completely turn OFF the regulator. The current drain from the input supply when OFF is only 50 μA. Pin 7 has an internal pullup current source of approximately 20 μA and a protection clamp Zener diode of 7 V to ground. When electrically driving the ON/$\overline{\text{OFF}}$ pin the high voltage level for the ON condition should not exceed the 6 V absolute maximum limit. When ON/OFF control is not required pin 7 should be left open circuited.

7.4 Device Functional Modes

7.4.1 Shutdown Mode

The ON/$\overline{\text{OFF}}$ pin provides electrical ON and OFF control for the LM2678. When the voltage of this pin is lower than 1.4 V, the device enters shutdown mode. The typical standby current in this mode is 45 μA.

7.4.2 Active Mode

When the voltage of the ON/$\overline{\text{OFF}}$ pin is higher than 1.4 V, the device starts switching and the output voltage rises until it reaches a normal regulation voltage.

8 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

8.1.1 Design Considerations

Power supply design using the LM2678 is greatly simplified by using recommended external components. A wide range of inductors, capacitors, and Schottky diodes from several manufacturers have been evaluated for use in designs that cover the full range of capabilities (input voltage, output voltage, and load current) of the LM2678. A simple design procedure using nomographs and component tables provided in this data sheet leads to a working design with very little effort.

The individual components from the various manufacturers called out for use are still just a small sample of the vast array of components available in the industry. While these components are recommended, they are not exclusively the only components for use in a design. After a close comparison of component specifications, equivalent devices from other manufacturers could be substituted for use in an application.

Important considerations for each external component and an explanation of how the nomographs and selection tables were developed follows.

8.1.2 Inductor

The inductor is the key component in a switching regulator. For efficiency the inductor stores energy during the switch ON time and then transfers energy to the load while the switch is OFF.

Nomographs are used to select the inductance value required for a given set of operating conditions. The nomographs assume that the circuit is operating in continuous mode (the current flowing through the inductor never falls to zero). The magnitude of inductance is selected to maintain a maximum ripple current of 30% of the maximum load current. If the ripple current exceeds this 30% limit the next larger value is selected.

The inductors offered have been specifically manufactured to provide proper operation under all operating conditions of input and output voltage and load current. Several part types are offered for a given amount of inductance. Both surface mount and through-hole devices are available. The inductors from each of the three manufacturers have unique characteristics.

- Renco: ferrite stick core inductors; benefits are typically lowest cost and can withstand ripple and transient peak currents above the rated value. These inductors have an external magnetic field, which may generate EMI.
- Pulse Engineering: powdered iron toroid core inductors; these also can withstand higher than rated currents and, being toroid inductors, have low EMI.
- Coilcraft: ferrite drum core inductors; these are the smallest physical size inductors and are available only as surface mount components. These inductors also generate EMI but less than stick inductors.

8.1.3 Output Capacitor

The output capacitor acts to smooth the DC output voltage and also provides energy storage. Selection of an output capacitor, with an associated equivalent series resistance (ESR), impacts both the amount of output ripple voltage and stability of the control loop.

The output ripple voltage of the power supply is the product of the capacitor ESR and the inductor ripple current. The capacitor types recommended in the tables were selected for having low ESR ratings.

In addition, both surface mount tantalum capacitors and through-hole aluminum electrolytic capacitors are offered as solutions.

Application Information (continued)

Impacting frequency stability of the overall control loop, the output capacitance, in conjunction with the inductor, creates a double pole inside the feedback loop. In addition the capacitance and the ESR value create a zero. These frequency response effects together with the internal frequency compensation circuitry of the LM2678 modify the gain and phase shift of the closed-loop system.

As a general rule for stable switching regulator circuits it is desired to have the unity gain bandwidth of the circuit to be limited to no more than one-sixth of the controller switching frequency. With the fixed 260-kHz switching frequency of the LM2678, the output capacitor is selected to provide a unity gain bandwidth of 40 kHz maximum. Each recommended capacitor value has been chosen to achieve this result.

In some cases multiple capacitors are required either to reduce the ESR of the output capacitor, to minimize output ripple (a ripple voltage of 1% of V_{OUT} or less is the assumed performance condition), or to increase the output capacitance to reduce the closed loop unity gain bandwidth (to less than 40 kHz). When parallel combinations of capacitors are required it has been assumed that each capacitor is the exact same part type.

The RMS current and working voltage (WV) ratings of the output capacitor are also important considerations. In a typical step-down switching regulator, the inductor ripple current (set to be no more than 30% of the maximum load current by the inductor selection) is the current that flows through the output capacitor. The capacitor RMS current rating must be greater than this ripple current. The voltage rating of the output capacitor should be greater than 1.3 times the maximum output voltage of the power supply. If operation of the system at elevated temperatures is required, the capacitor voltage rating may be de-rated to less than the nominal room temperature rating. Careful inspection of the manufacturer's specification for de-rating of working voltage with temperature is important.

8.1.4 Input Capacitor

Fast changing currents in high current switching regulators place a significant dynamic load on the unregulated power source. An input capacitor helps to provide additional current to the power supply as well as smooth out input voltage variations.

Like the output capacitor, the key specifications for the input capacitor are RMS current rating and working voltage. The RMS current flowing through the input capacitor is equal to one-half of the maximum DC load current so the capacitor should be rated to handle this. Paralleling multiple capacitors proportionally increases the current rating of the total capacitance. The voltage rating should also be selected to be 1.3 times the maximum input voltage. Depending on the unregulated input power source, under light load conditions the maximum input voltage could be significantly higher than normal operation and should be considered when selecting an input capacitor.

The input capacitor must be placed very close to the input pin of the LM2678. Due to relative high current operation with fast transient changes, the series inductance of input connecting wires or PCB traces can create ringing signals at the input terminal which could possibly propagate to the output or other parts of the circuitry. It may be necessary in some designs to add a small valued (0.1 μF to 0.47 μF) ceramic type capacitor in parallel with the input capacitor to prevent or minimize any ringing.

8.1.5 Catch Diode

When the power switch in the LM2678 turns OFF, the current through the inductor continues to flow. The path for this current is through the diode connected between the switch output and ground. This forward biased diode clamps the switch output to a voltage less than ground. This negative voltage must be greater than −1 V so a low voltage drop (particularly at high current levels) Schottky diode is recommended. Total efficiency of the entire power supply is significantly impacted by the power lost in the output catch diode. The average current through the catch diode is dependent on the switch duty cycle (D) and is equal to the load current times (1-D). Use of a diode rated for much higher current than is required by the actual application helps to minimize the voltage drop and power loss in the diode.

During the switch ON time the diode will be reversed biased by the input voltage. The reverse voltage rating of the diode must be at least 1.3 times greater than the maximum input voltage.

Application Information (continued)

8.1.6 Boost Capacitor

The boost capacitor creates a voltage used to overdrive the gate of the internal power MOSFET. This improves efficiency by minimizing the ON-resistance of the switch and associated power loss. For all applications it is recommended to use a 0.01-µF, 50-V ceramic capacitor.

8.1.7 Additional Application Information

When the output voltage is greater than approximately 6 V, and the duty cycle at minimum input voltage is greater than approximately 50%, the designer should exercise caution in selection of the output filter components. When an application designed to these specific operating conditions is subjected to a current limit fault condition, it may be possible to observe a large hysteresis in the current limit. This can affect the output voltage of the device until the load current is reduced sufficiently to allow the current limit protection circuit to reset itself.

Under current limiting conditions, the LM267x is designed to respond in the following manner:

1. At the moment when the inductor current reaches the current limit threshold, the ON-pulse is immediately terminated. This happens for any application condition.
2. However, the current limit block is also designed to momentarily reduce the duty cycle to below 50% to avoid subharmonic oscillations, which could cause the inductor to saturate.
3. Thereafter, once the inductor current falls below the current limit threshold, there is a small relaxation time during which the duty cycle progressively rises back above 50% to the value required to achieve regulation.

If the output capacitance is sufficiently *large*, it may be possible that as the output tries to recover, the output capacitor charging current is large enough to repeatedly re-trigger the current limit circuit before the output has fully settled. This condition is exacerbated with higher output voltage settings because the energy requirement of the output capacitor varies as the square of the output voltage (½ CV^2), thus requiring an increased charging current.

A simple test to determine if this condition might exist for a suspect application is to apply a short circuit across the output of the converter, and then remove the shorted output condition. In an application with properly selected external components, the output will recover smoothly.

Practical values of external components that have been experimentally found to work well under these specific operating conditions are C_{OUT} = 47 µF, L = 22 µH. It should be noted that even with these components, for a device's current limit of I_{CLIM}, the maximum load current under which the possibility of the large current limit hysteresis can be minimized is $I_{CLIM}/2$. For example, if the input is 24 V and the set output voltage is 18 V, then for a desired maximum current of 1.5 A, the current limit of the chosen switcher must be confirmed to be at least 3 A.

Under extreme overcurrent or short circuit conditions, the LM267X employs frequency foldback in addition to the current limit. If the cycle-by-cycle inductor current increases above the current limit threshold (due to short circuit or inductor saturation for example) the switching frequency is automatically reduced to protect the IC. Frequency below 100 kHz is typical for an extreme short-circuit condition.

8.2 Typical Application

8.2.1 All Output Voltage Versions

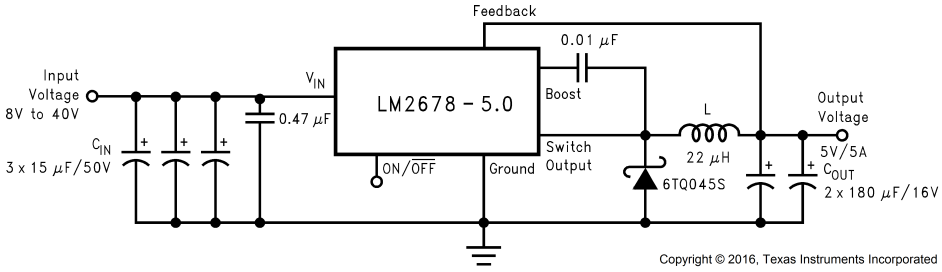


Figure 16. Typical Application for All Output Voltage Versions

Typical Application (continued)

8.2.1.1 Design Requirements

Select the power supply operating conditions and the maximum output current and follow below procedures to find the external components for LM2678.

8.2.1.2 Detailed Design Procedure

8.2.1.2.1 Custom Design With WEBENCH® Tools

Click here to create a custom design using the LM2678 device with the WEBENCH® Power Designer.

1. Start by entering the input voltage (V_{IN}), output voltage (V_{OUT}), and output current (I_{OUT}) requirements.
2. Optimize the design for key parameters such as efficiency, footprint, and cost using the optimizer dial.
3. Compare the generated design with other possible solutions from Texas Instruments.

The WEBENCH Power Designer provides a customized schematic along with a list of materials with real-time pricing and component availability.

In most cases, these actions are available:

- Run electrical simulations to see important waveforms and circuit performance
- Run thermal simulations to understand board thermal performance
- Export customized schematic and layout into popular CAD formats
- Print PDF reports for the design, and share the design with colleagues

Get more information about WEBENCH tools at www.ti.com/WEBENCH.

Using the nomographs and tables in this data sheet (or use the available design software at www.ti.com) a complete step-down regulator can be designed in a few simple steps.

Step 1: Define the power supply operating conditions:

- Required output voltage
- Maximum DC input voltage
- Maximum output load current

Step 2: Set the output voltage by selecting a fixed output LM2678 (3.3-V, 5-V, or 12-V applications) or determine the required feedback resistors for use with the adjustable LM2678−ADJ

Step 3: Determine the inductor required by using one of the four nomographs, Figure 17 through Figure 20. Table 3 provides a specific manufacturer and part number for the inductor.

Step 4: Using Table 5 (fixed output voltage) or Table 9 (adjustable output voltage), determine the output capacitance required for stable operation. Table 1 provides the specific capacitor type from the manufacturer of choice.

Step 5: Determine an input capacitor from Table 5 for fixed output voltage applications. Use Table 1 to find the specific capacitor type. For adjustable output circuits select a capacitor from Table 1 with a sufficient working voltage (WV) rating greater than V_{IN} max, and an RMS current rating greater than one-half the maximum load current (2 or more capacitors in parallel may be required).

Step 6: Select a diode from Table 4. The current rating of the diode must be greater than I_{LOAD} max and the reverse voltage rating must be greater than V_{IN} maximum.

Step 7: Include a 0.01-µF, 50-V capacitor for C_{BOOST} in the design.

8.2.1.2.2 Capacitor Selection Guides

Table 1. Input and Output Capacitor Codes – Surface Mount

CAPACITOR REFERENCE CODE	SURFACE MOUNT								
	AVX TPS SERIES			SPRAGUE 594D SERIES			KEMET T495 SERIES		
	C (µF)	WV (V)	Irms (A)	C (µF)	WV (V)	Irms (A)	C (µF)	WV (V)	Irms (A)
C1	330	6.3	1.15	120	6.3	1.1	100	6.3	0.82
C2	100	10	1.1	220	6.3	1.4	220	6.3	1.1

Typical Application (continued)

Table 1. Input and Output Capacitor Codes – Surface Mount (continued)

CAPACITOR REFERENCE CODE	SURFACE MOUNT								
	AVX TPS SERIES			SPRAGUE 594D SERIES			KEMET T495 SERIES		
	C (µF)	WV (V)	Irms (A)	C (µF)	WV (V)	Irms (A)	C (µF)	WV (V)	Irms (A)
C3	220	10	1.15	68	10	1.05	330	6.3	1.1
C4	47	16	0.89	150	10	1.35	100	10	1.1
C5	100	16	1.15	47	16	1	150	10	1.1
C6	33	20	0.77	100	16	1.3	220	10	1.1
C7	68	20	0.94	180	16	1.95	33	20	0.78
C8	22	25	0.77	47	20	1.15	47	20	0.94
C9	10	35	0.63	33	25	1.05	68	20	0.94
C10	22	35	0.66	68	25	1.6	10	35	0.63
C11	—	—	—	15	35	0.75	22	35	0.63
C12	—	—	—	33	35	1	4.7	50	0.66
C13	—	—	—	15	50	0.9	—	—	—

Table 2. Input and Output Capacitor Codes – Through Hole

CAPACITOR REFERENCE CODE	THROUGH HOLE											
	SANYO OS-CON SA SERIES			SANYO MV-GX SERIES			NICHICON PL SERIES			PANASONIC HFQ SERIES		
	C (µF)	WV (V)	Irms (A)	C (µF)	WV (V)	Irms (A)	C (µF)	WV (V)	Irms (A)	C (µF)	WV (V)	Irms (A)
C1	47	6.3	1	1000	6.3	0.8	680	10	0.8	82	35	0.4
C2	150	6.3	1.95	270	16	0.6	820	10	0.98	120	35	0.44
C3	330	6.3	2.45	470	16	0.75	1000	10	1.06	220	35	0.76
C4	100	10	1.87	560	16	0.95	1200	10	1.28	330	35	1.01
C5	220	10	2.36	820	16	1.25	2200	10	1.71	560	35	1.4
C6	33	16	0.96	1000	16	1.3	3300	10	2.18	820	35	1.62
C7	100	16	1.92	150	35	0.65	3900	10	2.36	1000	35	1.73
C8	150	16	2.28	470	35	1.3	6800	10	2.68	2200	35	2.8
C9	100	20	2.25	680	35	1.4	180	16	0.41	56	50	0.36
C10	47	25	2.09	1000	35	1.7	270	16	0.55	100	50	0.5
C11	—	—	—	220	63	0.76	470	16	0.77	220	50	0.92
C12	—	—	—	470	63	1.2	680	16	1.02	470	50	1.44
C13	—	—	—	680	63	1.5	820	16	1.22	560	50	1.68
C14	—	—	—	1000	63	1.75	1800	16	1.88	1200	50	2.22
C15	—	—	—	—	—	—	220	25	0.63	330	63	1.42
C16	—	—	—	—	—	—	220	35	0.79	1500	63	2.51
C17	—	—	—	—	—	—	560	35	1.43	—	—	—
C18	—	—	—	—	—	—	2200	35	2.68	—	—	—
C19	—	—	—	—	—	—	150	50	0.82	—	—	—
C20	—	—	—	—	—	—	220	50	1.04	—	—	—
C21	—	—	—	—	—	—	330	50	1.3	—	—	—
C22	—	—	—	—	—	—	100	63	0.75	—	—	—
C23	—	—	—	—	—	—	390	63	1.62	—	—	—
C24	—	—	—	—	—	—	820	63	2.22	—	—	—
C25	—	—	—	—	—	—	1200	63	2.51	—	—	—

Table 3. Inductor Manufacturer Part Numbers

INDUCTOR REFERENCE NUMBER	INDUCTANCE (µH)	CURRENT (A)	RENCO		PULSE ENGINEERING		COILCRAFT
			THROUGH HOLE	SURFACE MOUNT	THROUGH HOLE	SURFACE MOUNT	SURFACE MOUNT
L23	33	1.35	RL-5471-7	RL1500-33	PE-53823	PE-53823S	DO3316-333
L24	22	1.65	RL-1283-22-43	RL1500-22	PE-53824	PE-53824S	DO3316-223
L25	15	2	RL-1283-15-43	RL1500-15	PE-53825	PE-53825S	DO3316-153
L29	100	1.41	RL-5471-4	RL-6050-100	PE-53829	PE-53829S	DO5022P-104
L30	68	1.71	RL-5471-5	RL6050-68	PE-53830	PE-53830S	DO5022P-683
L31	47	2.06	RL-5471-6	RL6050-47	PE-53831	PE-53831S	DO5022P-473
L32	33	2.46	RL-5471-7	RL6050-33	PE-53932	PE-53932S	DO5022P-333
L33	22	3.02	RL-1283-22-43	RL6050-22	PE-53933	PE-53933S	DO5022P-223
L34	15	3.65	RL-1283-15-43	—	PE-53934	PE-53934S	DO5022P-153
L38	68	2.97	RL-5472-2	—	PE-54038	PE-54038S	—
L39	47	3.57	RL-5472-3	—	PE-54039	PE-54039S	—
L40	33	4.26	RL-1283-33-43	—	PE-54040	PE-54040S	—
L41	22	5.22	RL-1283-22-43	—	PE-54041	P0841	—
L44	68	3.45	RL-5473-3	—	PE-54044	—	—
L45	10	4.47	RL-1283-10-43	—	—	P0845	DO5022P-103HC
L46	15	5.6	RL-1283-15-43	—	—	P0846	DO5022P-153HC
L47	10	5.66	RL-1283-10-43	—	—	P0847	DO5022P-103HC
L48	47	5.61	RL-1282-47-43	—	—	P0848	—
L49	33	5.61	RL-1282-33-43	—	—	P0849	—

Table 4. Schottky Diode Selection Table

REVERSE VOLTAGE (V)	SURFACE MOUNT		THROUGH HOLE	
	3 A	5 A OR MORE	3 A	5 A OR MORE
20	SK32	—	1N5820	—
			SR302	
30	SK33	MBRD835L	1N5821	—
	30WQ03F		31DQ03	
40	SK34	MBRD1545CT	1N5822	1N5825
	30BQ040	6TQ045S	MBR340	MBR745
	30WQ04F	—	31DQ04	80SQ045
	MBRS340	—	SR403	6TQ045
	MBRD340	—	—	—
50 or more	SK35	—	MBR350	—
	30WQ05F	—	31DQ05	—
	—	—	SR305	—

8.2.1.3 Application Curves

For continuous mode operation

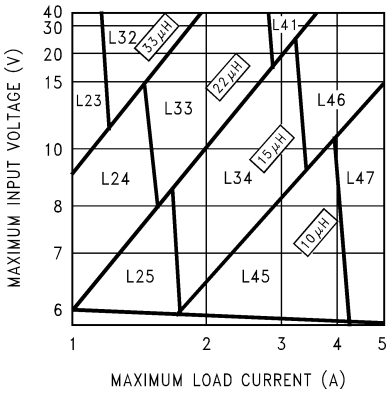


Figure 17. LM2678-3.3

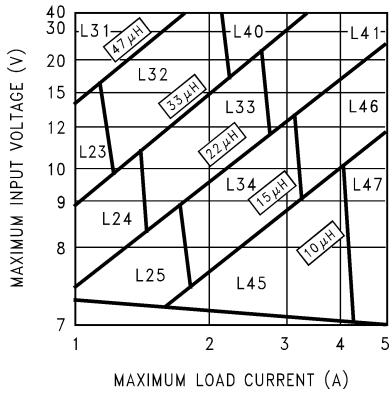


Figure 18. LM2678-5

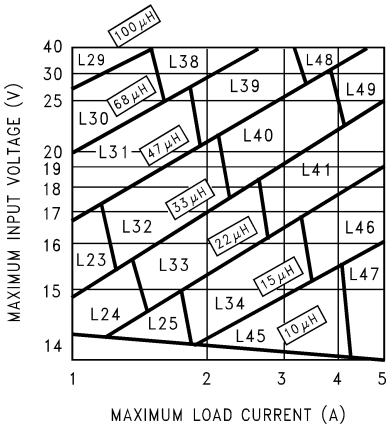


Figure 19. LM2678-12

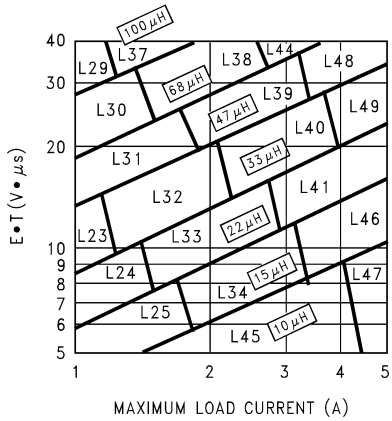


Figure 20. LM2678-Adjustable

8.2.2 Fixed Output Voltage Design Example

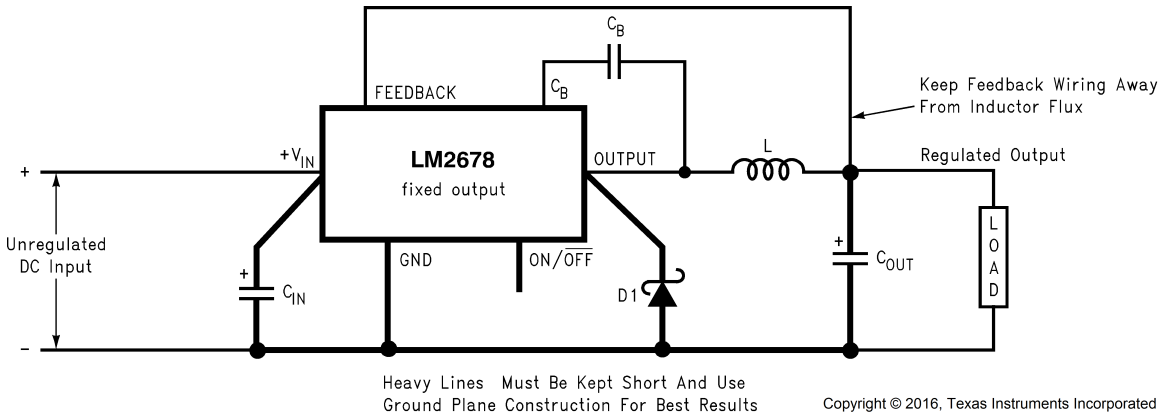


Figure 21. Basic Circuit for Fixed Output Voltage Applications

8.2.2.1 Detailed Design Procedure

A system logic power supply bus of 3.3 V is to be generated from a wall adapter which provides an unregulated DC voltage of 13 V to 16 V. The maximum load current is 4 A. Through-hole components are preferred.

Step 1: Operating conditions are:

- V_{OUT} = 3.3 V
- V_{IN} max = 16 V
- I_{LOAD} max = 4 A

Step 2: Select a LM2678 3.3-V. The output voltage has a tolerance of ±2% at room temperature and ±3% over the full operating temperature range.

Step 3: Use the nomograph for the 3.3-V device, Figure 17. The intersection of the 16-V horizontal line (V_{in} max) and the 4-A vertical line (I_{load} max) indicates that L46, a 15-µH inductor, is required.

From Table 3, L46 in a through-hole component is available from Renco with part number RL-1283-15-43.

Step 4: Use Table 5 to determine an output capacitor. With a 3.3-V output and a 15-µH inductor there are four through-hole output capacitor solutions with the number of same type capacitors to be paralleled and an identifying capacitor code given. Table 1 provides the actual capacitor characteristics. Any of the following choices work in the circuit:

- 2 × 220-µF, 10-V Sanyo OS-CON (code C5)
- 2 × 820-µF, 16-V Sanyo MV-GX (code C5)
- 1 × 3900-µF, 10-V Nichicon PL (code C7)
- 2 × 560-µF, 35-V Panasonic HFQ (code C5)

Step 5: Use Table 5 to select an input capacitor. With 3.3-V output and 15 µH there are three through-hole solutions. These capacitors provide a sufficient voltage rating and an RMS current rating greater than 2 A (1/2 I_{load} max). Again using Table 1 for specific component characteristics the following choices are suitable:

- 2 × 680-µF, 63-V Sanyo MV-GX (code C13)
- 1 × 1200-µF, 63-V Nichicon PL (code C25)
- 1 × 1500-µF, 63-V Panasonic HFQ (code C16)

Step 6: From Table 4 a 5-A or more Schottky diode must be selected. For through-hole components only 40-V rated diodes are indicated and 4 part types are suitable:

- 1N5825
- MBR745
- 80SQ045
- 6TQ045

Step 7: A 0.01-µF capacitor is used for C_{BOOST}.

8.2.2.1.1 Capacitor Selection

Table 5. Output Capacitors for Fixed Output Voltage Application—Surface Mount(1)(2)

OUTPUT VOLTAGE (V)	INDUCTANCE (µH)	SURFACE MOUNT					
		AVX TPS SERIES		SPRAGUE 594D SERIES		KEMET T495 SERIES	
		NO.	C CODE	NO.	C CODE	NO.	C CODE
3.3	10	5	C1	5	C1	5	C2
	15	4	C1	4	C1	4	C3
	22	3	C2	2	C7	3	C4
	33	1	C1	2	C7	3	C4
5	10	4	C2	4	C6	4	C4
	15	3	C3	2	C7	3	C5
	22	3	C2	2	C7	3	C4
	33	2	C2	2	C3	2	C4
	47	2	C2	1	C7	2	C4
12	10	4	C5	3	C6	5	C9
	15	3	C5	2	C7	4	C9
	22	2	C5	2	C6	3	C8
	33	2	C5	1	C7	3	C8
	47	2	C4	1	C6	2	C8
	68	1	C5	1	C5	2	C7
	100	1	C4	1	C5	1	C8

(1) No. represents the number of identical capacitor types to be connected in parallel.
(2) C Code indicates the Capacitor Reference number in Table 1 and Table 2 for identifying the specific component from the manufacturer.

Table 6. Output Capacitors for Fixed Output Voltage Application—Through Hole(1)(2)

OUTPUT VOLTAGE (V)	INDUCTANCE (µH)	THROUGH HOLE							
		SANYO OS-CON SA SERIES		SANYO MV-GX SERIES		NICHICON PL SERIES		PANASONIC HFQ SERIES	
		NO.	C CODE	NO.	C CODE	NO.	C CODE	NO.	C CODE
3.3	10	2	C5	2	C6	1	C8	2	C6
	15	2	C5	2	C5	1	C7	2	C5
	22	1	C5	1	C10	1	C5	1	C7
	33	1	C5	1	C10	1	C5	1	C7
5	10	2	C4	2	C5	1	C6	2	C5
	15	1	C5	1	C10	1	C5	1	C7
	22	1	C5	1	C9	1	C5	1	C5
	33	1	C4	1	C5	1	C4	1	C4
	47	1	C4	1	C4	1	C2	2	C4
12	10	2	C7	1	C10	1	C14	2	C4
	15	1	C8	1	C6	1	C17	1	C5
	22	1	C7	1	C5	1	C13	1	C5
	33	1	C7	1	C4	1	C12	1	C4
	47	1	C7	1	C3	1	C11	1	C3
	68	1	C6	1	C2	1	C10	1	C3
	100	1	C6	1	C2	1	C9	1	C1

(1) No. represents the number of identical capacitor types to be connected in parallel.
(2) C Code indicates the Capacitor Reference number in Table 1 and Table 2 for identifying the specific component from the manufacturer.

Table 7. Input Capacitors for Fixed Output Voltage Application—Surface Mount(1)(2) (3)

OUTPUT VOLTAGE (V)	INDUCTANCE (µH)	SURFACE MOUNT					
		AVX TPS SERIES		SPRAGUE 594D SERIES		KEMET T495 SERIES	
		NO.	C CODE	NO.	C CODE	NO.	C CODE
3.3	10	3	C7	2	C10	3	C9
	15	See(4)	See(4)	3	C13	4	C12
	22	See(4)	See(4)	2	C13	3	C12
	33	See(4)	See(4)	2	C13	3	C12
5	10	3	C4	2	C6	3	C9
	15	4	C9	3	C12	4	C10
	22	See(4)	See(4)	3	C13	4	C12
	33	See(4)	See(4)	2	C13	3	C12
	47	See(4)	See(4)	1	C13	2	C12
12	10	4	C9	2	C10	4	C10
	15	4	C8	2	C10	4	C10
	22	4	C9	3	C12	4	C10
	33	See(4)	See(4)	3	C13	4	C12
	47	See(4)	See(4)	2	C13	3	C12
	68	See(4)	See(4)	2	C13	2	C12
	100	See(4)	See(4)	1	C13	2	C12

(1) No. represents the number of identical capacitor types to be connected in parallel.
(2) C Code indicates the Capacitor Reference number in Table 1 and Table 2 for identifying the specific component from the manufacturer.
(3) Assumes worst case maximum input voltage and load current for a given inductance value.
(4) Check voltage rating of capacitors to be greater than application input voltage.

Table 8. Input Capacitors for Fixed Output Voltage Application—Through Hole(1)(2) (3)

OUTPUT VOLTAGE (V)	INDUCTANCE (µH)	THROUGH HOLE							
		SANYO OS-CON SA SERIES		SANYO MV-GX SERIES		NICHICON PL SERIES		PANASONIC HFQ SERIES	
		NO.	C CODE	NO.	C CODE	NO.	C CODE	NO.	C CODE
3.3	10	2	C9	2	C8	1	C18	1	C8
	15	See(4)	See(4)	2	C13	1	C25	1	C16
	22	See(4)	See(4)	1	C14	1	C24	1	C16
	33	See(4)	See(4)	1	C14	1	C24	1	C16
5	10	2	C7	2	C8	1	C25	1	C8
	15	See(4)	See(4)	2	C8	1	C25	1	C8
	22	See(4)	See(4)	2	C13	1	C25	1	C16
	33	See(4)	See(4)	1	C14	1	C23	1	C13
	47	See(4)	See(4)	1	C12	1	C19	1	C11
12	10	2	C10	2	C8	1	C18	1	C8
	15	2	C10	2	C8	1	C18	1	C8
	22	See(4)	See(4)	2	C8	1	C18	1	C8
	33	See(4)	See(4)	2	C12	1	C24	1	C14
	47	See(4)	See(4)	1	C14	1	C23	1	C13
	68	See(4)	See(4)	1	C13	1	C21	1	C15
	100	See(4)	See(4)	1	C11	1	C22	1	C11

(1) No. represents the number of identical capacitor types to be connected in parallel.
(2) C Code indicates the Capacitor Reference number in Table 1 and Table 2 for identifying the specific component from the manufacturer.
(3) Assumes worst case maximum input voltage and load current for a given inductance value.
(4) Check voltage rating of capacitors to be greater than application input voltage.

8.2.3 Adjustable Output Design Example

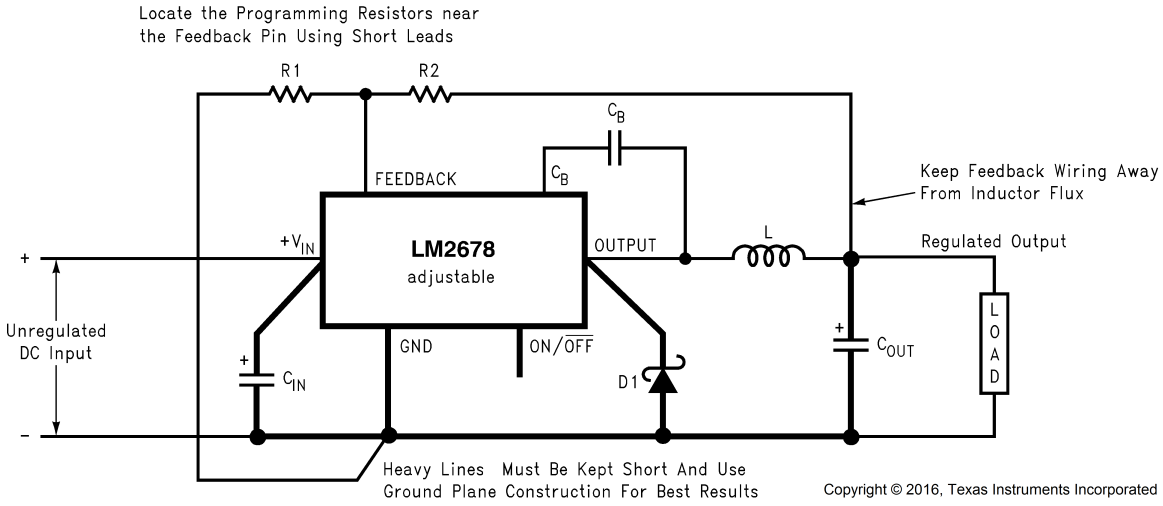


Figure 22. Basic Circuit for Adjustable Output Voltage Applications

8.2.3.1 Detailed Design Procedure

In this example it is desired to convert the voltage from a two battery automotive power supply (voltage range of 20 V to 28 V, typical in large truck applications) to the 14.8-VDC alternator supply typically used to power electronic equipment from single battery 12-V vehicle systems. The load current required is 3.5 A maximum. It is also desired to implement the power supply with all surface mount components.

Step 1: Operating conditions are:

- V_{OUT} = 14.8 V
- V_{IN} max = 28 V
- I_{LOAD} max = 3.5 A

Step 2: Select an LM2678S-ADJ. To set the output voltage to 14.9-V two resistors need to be chosen (R1 and R2 in Figure 22). For the adjustable device the output voltage is set by Equation 1.

$$V_{OUT} = V_{FB}\left(1 + \frac{R_2}{R_1}\right) \quad (1)$$

where

- V_{FB} is the feedback voltage of typically 1.21 V

A recommended value to use for R1 is 1k. In this example then R2 is determined with Equation 2.

$$R_2 = R_1\left(\frac{V_{OUT}}{V_{FB}} - 1\right) = 1\,k\Omega\left(\frac{14.8V}{1.21V} - 1\right) \quad (2)$$

where

- R2 = 11.23 kΩ

The closest standard 1% tolerance value to use is 11.3 kΩ.

This sets the nominal output voltage to 14.88 V which is within 0.5% of the target value.

Step 3: To use the nomograph for the adjustable device, Figure 20, requires a calculation of the inductor Volt • microsecond constant (E • T expressed in V • μS) from Equation 3.

$$E \cdot T = \left(V_{IN(MAX)} - V_{OUT} - V_{SAT}\right) \cdot \frac{V_{OUT} + V_D}{V_{IN(MAX)} - V_{SAT} + V_D} \cdot \frac{1000}{260}\ (V \cdot \mu s) \quad (3)$$

where

- V_{SAT} is the voltage drop across the internal power switch which is $R_{ds(ON)}$ times I_{load}

In this example this would be typically 0.12 Ω × 3.5 A or 0.42 V and V_D is the voltage drop across the forward biased Schottky diode, typically 0.5 V. The switching frequency of 260 kHz is the nominal value to use to estimate the ON time of the switch during which energy is stored in the inductor.

For this example, E • T is found with Equation 4 and Equation 5.

$$E \cdot T = (28 - 14.8 - 0.42) \cdot \frac{14.8 + 0.5}{28 - 0.42 + 0.5} \cdot \frac{1000}{260} \ (V \cdot \mu s) \quad (4)$$

$$E \cdot T = (12.78V) \cdot \frac{15.3V}{28.08V} \cdot 3.85 \ (V \cdot \mu s) = 26.8 \ (V \cdot \mu s) \quad (5)$$

Using Figure 20, the intersection of 27 V • μS horizontally and the 3.5 A vertical line (I_{LOAD} max) indicates that L48 , a 47-μH inductor, or L49, a 33-μH inductor could be used. Either inductor will be suitable, but for this example selecting the larger inductance results in lower ripple current.

From Table 3, L48 in a surface mount component is available from Pulse Engineering with part number P0848.

Step 4: Use Table 9 to determine an output capacitor. With a 14.8-V output the 12.5 to 15 V row is used and with a 47-μH inductor there are three surface mount output capacitor solutions. Table 1 provides the actual capacitor characteristics based on the C Code number. Any of the following choices can be used:

- 1 × 33-μF, 20-V AVX TPS (code C6)
- 1 × 47-μF, 20-V Sprague 594 (code C8)
- 1 × 47-μF, 20-V Kemet T495 (code C8)

NOTE

When using the adjustable device in low voltage applications (less than 3-V output), if the nomograph Figure 20 selects an inductance of 22 μH or less Table 9 and Table 10 do not provide an output capacitor solution. With these conditions the number of output capacitors required for stable operation becomes impractical. TI recommends using either a 33-μH or 47-μH inductor and the output capacitors from Table 9 and Table 10.

Step 5: An input capacitor for this example requires at least a 35-V WV rating with an RMS current rating of 1.75 A (1/2 I_{OUT} max). Table 1 shows that C12, a 33-μF, 35-V capacitor from Sprague, has the highest voltage and current rating of the surface mount components and that two of these capacitor in parallel are adequate.

Step 6: From Table 4 a 5-A or more Schottky diode must be selected. For surface mount diodes with a margin of safety on the voltage rating one of two diodes can be used:

- MBRD1545CT
- 6TQ045S

Step 7: A 0.01-μF capacitor is used for C_{BOOST}.

8.2.3.1.1 Capacitor Selection

Table 9. Output Capacitors for Adjustable Output Voltage Applications—Surface Mount(1)(2)

OUTPUT VOLTAGE (V)	INDUCTANCE (μH)	SURFACE MOUNT					
		AVX TPS SERIES		SPRAGUE 594D SERIES		KEMET T495 SERIES	
		NO.	C CODE	NO.	C CODE	NO.	C CODE
1.21 to 2.5	33(3)	7	C1	6	C2	7	C3
	47(3)	5	C1	4	C2	5	C3
2.5 to 3.75	33(3)	4	C1	3	C2	4	C3
	47(3)	3	C1	2	C2	3	C3
3.75 to 5	22	4	C1	3	C2	4	C3
	33	3	C1	2	C2	3	C3
	47	2	C1	2	C2	2	C3

(1) No. represents the number of identical capacitor types to be connected in parallel.
(2) C Code indicates the Capacitor Reference number in Table 1 and Table 2 for identifying the specific component from the manufacturer.
(3) Set to a higher value for a practical design solution.

Table 9. Output Capacitors for Adjustable Output Voltage Applications—Surface Mount[1][2] (continued)

OUTPUT VOLTAGE (V)	INDUCTANCE (µH)	SURFACE MOUNT					
		AVX TPS SERIES		SPRAGUE 594D SERIES		KEMET T495 SERIES	
		NO.	C CODE	NO.	C CODE	NO.	C CODE
5 to 6.25	22	3	C2	3	C3	3	C4
	33	2	C2	2	C3	2	C4
	47	2	C2	2	C3	2	C4
	68	1	C2	1	C3	1	C4
6.25 to 7.5	22	3	C2	1	C4	3	C4
	33	2	C2	1	C3	2	C4
	47	1	C3	1	C4	1	C6
	68	1	C2	1	C3	1	C4
7.5 to 10	33	2	C5	1	C6	2	C8
	47	1	C5	1	C6	2	C8
	68	1	C5	1	C6	1	C8
	100	1	C4	1	C5	1	C8
10 to 12.5	33	1	C5	1	C6	2	C8
	47	1	C5	1	C6	2	C8
	68	1	C5	1	C6	1	C8
	100	1	C5	1	C6	1	C8
12.5 to 15	33	1	C6	1	C8	1	C8
	47	1	C6	1	C8	1	C8
	68	1	C6	1	C8	1	C8
	100	1	C6	1	C8	1	C8
15 to 20	33	1	C8	1	C10	2	C10
	47	1	C8	1	C9	2	C10
	68	1	C8	1	C9	2	C10
	100	1	C8	1	C9	1	C10
20 to 30	33	2	C9	2	C11	2	C11
	47	1	C10	1	C12	1	C11
	68	1	C9	1	C12	1	C11
	100	1	C9	1	C12	1	C11
30 to 37	10	No values available		4	C13	8	C12
	15			3	C13	5	C12
	22			2	C13	4	C12
	33			1	C13	3	C12
	47			1	C13	2	C12
	68			1	C13	2	C12

Table 10. Output Capacitors for Adjustable Output Voltage Applications—Through Hole(1)(2)

OUTPUT VOLTAGE (V)	INDUCTANCE (µH)	THROUGH HOLE							
		SANYO OS-CON SA SERIES		SANYO MV-GX SERIES		NICHICON PL SERIES		PANASONIC HFQ SERIES	
		NO.	C CODE	NO.	C CODE	NO.	C CODE	NO.	C CODE
1.21 to 2.5	33(3)	2	C3	5	C1	5	C3	3	C
	47(3)	2	C2	4	C1	3	C3	2	C5
2.5 to 3.75	33(3)	1	C3	3	C1	3	C1	2	C5
	47(3)	1	C2	2	C1	2	C3	1	C5
3.75 to 5	22	1	C3	3	C1	3	C1	2	C5
	33	1	C2	2	C1	2	C1	1	C5
	47	1	C2	2	C1	1	C3	1	C5
5 to 6.25	22	1	C5	2	C6	2	C3	2	C5
	33	1	C4	1	C6	2	C1	1	C5
	47	1	C4	1	C6	1	C3	1	C5
	68	1	C4	1	C6	1	C1	1	C5
6.25 to 7.5	22	1	C5	1	C6	2	C1	1	C5
	33	1	C4	1	C6	1	C3	1	C5
	47	1	C4	1	C6	1	C1	1	C5
	68	1	C4	1	C2	1	C1	1	C5
7.5 to 10	33	1	C7	1	C6	1	C14	1	C5
	47	1	C7	1	C6	1	C14	1	C5
	68	1	C7	1	C2	1	C14	1	C2
	100	1	C7	1	C2	1	C14	1	C2
10 to 12.5	33	1	C7	1	C6	1	C14	1	C5
	47	1	C7	1	C2	1	C14	1	C5
	68	1	C7	1	C2	1	C9	1	C2
	100	1	C7	1	C2	1	C9	1	C2
12.5 to 15	33	1	C9	1	C10	1	C15	1	C2
	47	1	C9	1	C10	1	C15	1	C2
	68	1	C9	1	C10	1	C15	1	C2
	100	1	C9	1	C10	1	C15	1	C2
15 to 20	33	1	C10	1	C7	1	C15	1	C2
	47	1	C10	1	C7	1	C15	1	C2
	68	1	C10	1	C7	1	C15	1	C2
	100	1	C10	1	C7	1	C15	1	C2
20 to 30	33	No values available		1	C7	1	C16	1	C2
	47			1	C7	1	C16	1	C2
	68			1	C7	1	C16	1	C2
	100			1	C7	1	C16	1	C2
30 to 37	10	No values available		1	C12	1	C20	1	C10
	15			1	C11	1	C20	1	C11
	22			1	C11	1	C20	1	C10
	33			1	C11	1	C20	1	C10
	47			1	C11	1	C20	1	C10
	68			1	C11	1	C20	1	C10

(1) No. represents the number of identical capacitor types to be connected in parallel.
(2) C Code indicates the Capacitor Reference number in Table 1 and Table 2 for identifying the specific component from the manufacturer.
(3) Set to a higher value for a practical design solution.

9 Power Supply Recommendations

The LM2678 is designed to operate from an input voltage supply up to 40 V. This input supply must be well regulated and able to withstand maximum input current and maintain a stable voltage.

10 Layout

10.1 Layout Guidelines

Board layout is critical for the proper operation of switching power supplies. First, the ground plane area must be sufficient for thermal dissipation purposes. Second, appropriate guidelines must be followed to reduce the effects of switching noise. Switch mode converters are very fast switching devices. In such cases, the rapid increase of input current combined with the parasitic trace inductance generates unwanted L di/dt noise spikes. The magnitude of this noise tends to increase as the output current increases. This noise may turn into electromagnetic interference (EMI) and can also cause problems in device performance. Therefore, take care in layout to minimize the effect of this switching noise. The most important layout rule is to keep the AC current loops as small as possible. Figure 23 shows the current flow in a buck converter. The top schematic shows a dotted line which represents the current flow during the top switch ON-state. The middle schematic shows the current flow during the top switch OFF-state. The bottom schematic shows the currents referred to as AC currents. These AC currents are the most critical because they are changing in a very short time period. The dotted lines of the bottom schematic are the traces to keep as short and wide as possible. This will also yield a small loop area reducing the loop inductance. To avoid functional problems due to layout, review the PCB layout example. Best results are achieved if the placement of the LM2679 device, the bypass capacitor, the Schottky diode, RFBB, RFBT, and the inductor are placed as shown in the example. Note that, in the layout shown, R1 = RFBB and R2 = RFBT. It is also recommended to use 2-oz. copper boards or heavier to help thermal dissipation and to reduce the parasitic inductances of board traces. See *AN-1229 SIMPLE SWITCHER® PCB Layout Guidelines* for more information.

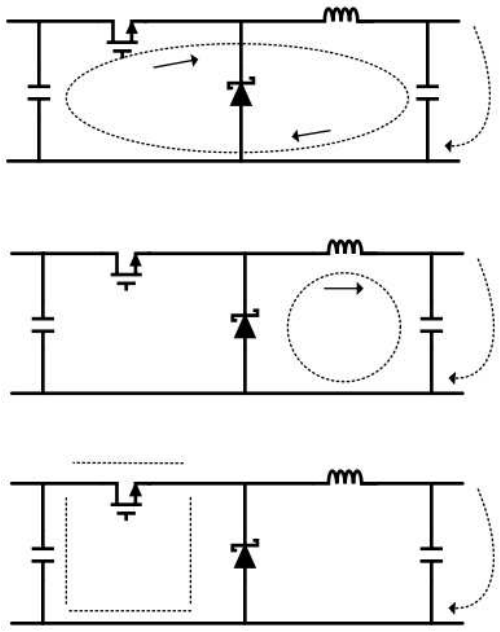


Figure 23. Typical Current Flow in Buck Regulator

10.2 Layout Example

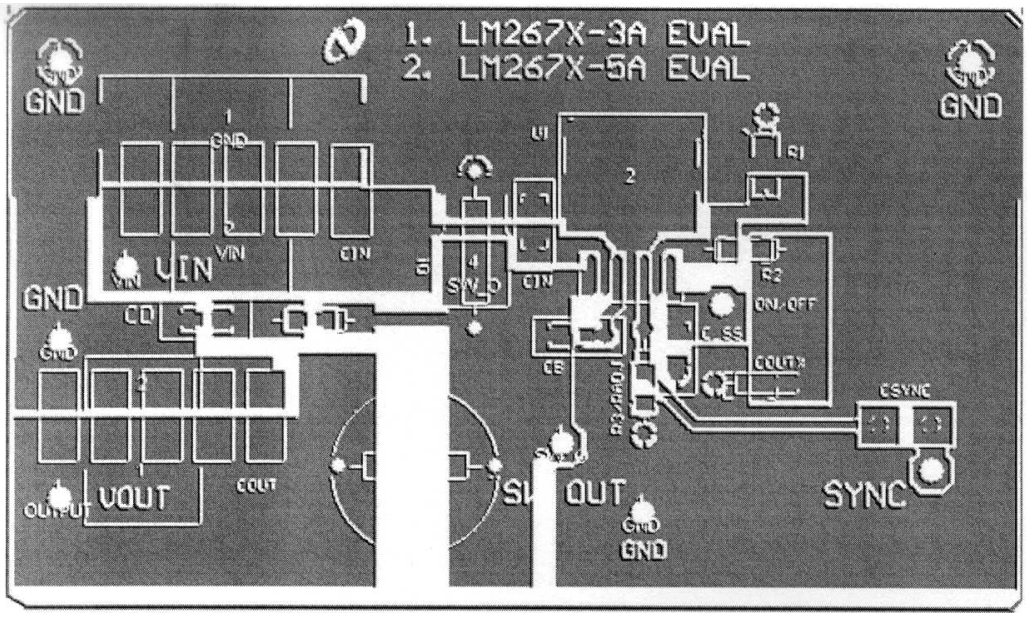


Figure 24. Top Layer Foil Pattern of Printed-Circuit Board

11 Device and Documentation Support

11.1 Custom Design With WEBENCH® Tools

Click here to create a custom design using the LM2678 device with the WEBENCH® Power Designer.

1. Start by entering the input voltage (V_{IN}), output voltage (V_{OUT}), and output current (I_{OUT}) requirements.
2. Optimize the design for key parameters such as efficiency, footprint, and cost using the optimizer dial.
3. Compare the generated design with other possible solutions from Texas Instruments.

The WEBENCH Power Designer provides a customized schematic along with a list of materials with real-time pricing and component availability.

In most cases, these actions are available:

- Run electrical simulations to see important waveforms and circuit performance
- Run thermal simulations to understand board thermal performance
- Export customized schematic and layout into popular CAD formats
- Print PDF reports for the design, and share the design with colleagues

Get more information about WEBENCH tools at www.ti.com/WEBENCH.

11.2 Related Documentation

For related documentation see the following:

- *AN-1187 Leadless Leadfram Package (LLP)* (SNOA401)
- *AN-1229 SIMPLE SWITCHER® PCB Layout Guidelines* (SNVA054)

11.3 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

11.4 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

11.5 Trademarks

E2E is a trademark of Texas Instruments.
SIMPLE SWITCHER, WEBENCH are registered trademarks of Texas Instruments.
All other trademarks are the property of their respective owners.

11.6 Electrostatic Discharge Caution

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

11.7 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

12.1 VSON Package Devices

The LM2678 is offered in the 14-pin VSON surface mount package to allow for a significantly decreased footprint with equivalent power dissipation compared to the DDPAK. For details on mounting and soldering specifications, refer to *AN-1187 Leadless Leadfram Package (LLP)*.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM2678S-12	NRND	DDPAK/ TO-263	KTW	7	45	TBD	Call TI	Call TI	-40 to 125	LM2678 S-12	
LM2678S-12/NOPB	ACTIVE	DDPAK/ TO-263	KTW	7	45	Pb-Free (RoHS Exempt)	CU SN	Level-3-245C-168 HR	-40 to 125	LM2678 S-12	Samples
LM2678S-3.3	NRND	DDPAK/ TO-263	KTW	7	45	TBD	Call TI	Call TI	-40 to 125	LM2678 S-3.3	
LM2678S-3.3/NOPB	ACTIVE	DDPAK/ TO-263	KTW	7	45	Pb-Free (RoHS Exempt)	CU SN	Level-3-245C-168 HR	-40 to 125	LM2678 S-3.3	Samples
LM2678S-5.0	NRND	DDPAK/ TO-263	KTW	7	45	TBD	Call TI	Call TI	-40 to 125	LM2678 S-5.0	
LM2678S-5.0/NOPB	ACTIVE	DDPAK/ TO-263	KTW	7	45	Pb-Free (RoHS Exempt)	CU SN	Level-3-245C-168 HR	-40 to 125	LM2678 S-5.0	Samples
LM2678S-ADJ	NRND	DDPAK/ TO-263	KTW	7	45	TBD	Call TI	Call TI	-40 to 125	LM2678 S-ADJ	
LM2678S-ADJ/NOPB	ACTIVE	DDPAK/ TO-263	KTW	7	45	Pb-Free (RoHS Exempt)	CU SN	Level-3-245C-168 HR	-40 to 125	LM2678 S-ADJ	Samples
LM2678SD-12	NRND	VSON	NHM	14	250	TBD	Call TI	Call TI	-40 to 125	S0003BB	
LM2678SD-12/NOPB	ACTIVE	VSON	NHM	14	250	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	S0003BB	Samples
LM2678SD-3.3/NOPB	ACTIVE	VSON	NHM	14	250	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	S0003CB	Samples
LM2678SD-5.0/NOPB	ACTIVE	VSON	NHM	14	250	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	S0003DB	Samples
LM2678SD-ADJ	NRND	VSON	NHM	14	250	TBD	Call TI	Call TI	-40 to 125	S0003EB	
LM2678SD-ADJ/NOPB	ACTIVE	VSON	NHM	14	250	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	S0003EB	Samples
LM2678SDX-3.3/NOPB	ACTIVE	VSON	NHM	14	2500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	S0003CB	Samples
LM2678SDX-5.0/NOPB	ACTIVE	VSON	NHM	14	2500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	S0003DB	Samples
LM2678SDX-ADJ/NOPB	ACTIVE	VSON	NHM	14	2500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	S0003EB	Samples
LM2678SX-12/NOPB	ACTIVE	DDPAK/ TO-263	KTW	7	500	Pb-Free (RoHS Exempt)	CU SN	Level-3-245C-168 HR	-40 to 125	LM2678 S-12	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM2678SX-3.3/NOPB	ACTIVE	DDPAK/ TO-263	KTW	7	500	Pb-Free (RoHS Exempt)	CU SN	Level-3-245C-168 HR	-40 to 125	LM2678 S-3.3	Samples
LM2678SX-5.0	NRND	DDPAK/ TO-263	KTW	7	500	TBD	Call TI	Call TI	-40 to 125	LM2678 S-5.0	
LM2678SX-5.0/NOPB	ACTIVE	DDPAK/ TO-263	KTW	7	500	Pb-Free (RoHS Exempt)	CU SN	Level-3-245C-168 HR	-40 to 125	LM2678 S-5.0	Samples
LM2678SX-ADJ	NRND	DDPAK/ TO-263	KTW	7	500	TBD	Call TI	Call TI	-40 to 125	LM2678 S-ADJ	
LM2678SX-ADJ/NOPB	ACTIVE	DDPAK/ TO-263	KTW	7	500	Pb-Free (RoHS Exempt)	CU SN	Level-3-245C-168 HR	-40 to 125	LM2678 S-ADJ	Samples
LM2678T-12/NOPB	ACTIVE	TO-220	NDZ	7	45	Green (RoHS & no Sb/Br)	CU SN	Level-1-NA-UNLIM	-40 to 125	LM2678 T-12	Samples
LM2678T-3.3/NOPB	ACTIVE	TO-220	NDZ	7	45	Green (RoHS & no Sb/Br)	CU SN	Level-1-NA-UNLIM	-40 to 125	LM2678 T-3.3	Samples
LM2678T-5.0	NRND	TO-220	NDZ	7	45	TBD	Call TI	Call TI	-40 to 125	LM2678 T-5.0	
LM2678T-5.0/NOPB	ACTIVE	TO-220	NDZ	7	45	Green (RoHS & no Sb/Br)	CU SN	Level-1-NA-UNLIM	-40 to 125	LM2678 T-5.0	Samples
LM2678T-ADJ	NRND	TO-220	NDZ	7	45	TBD	Call TI	Call TI	-40 to 125	LM2678 T-ADJ	
LM2678T-ADJ/NOPB	ACTIVE	TO-220	NDZ	7	45	Green (RoHS & no Sb/Br)	CU SN	Level-1-NA-UNLIM	-40 to 125	LM2678 T-ADJ	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

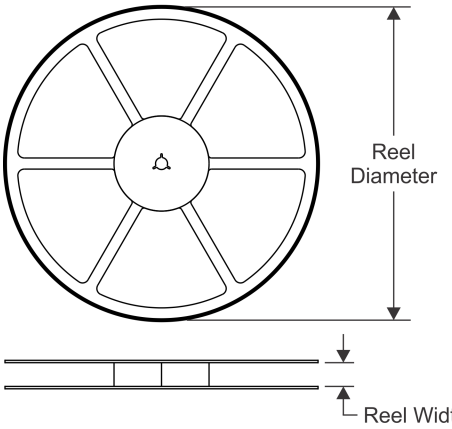
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

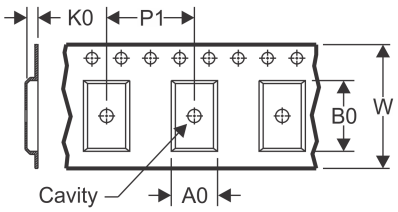
(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

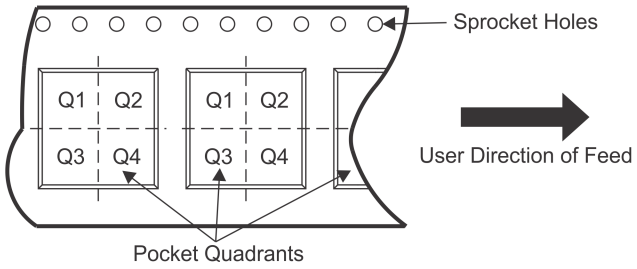


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE

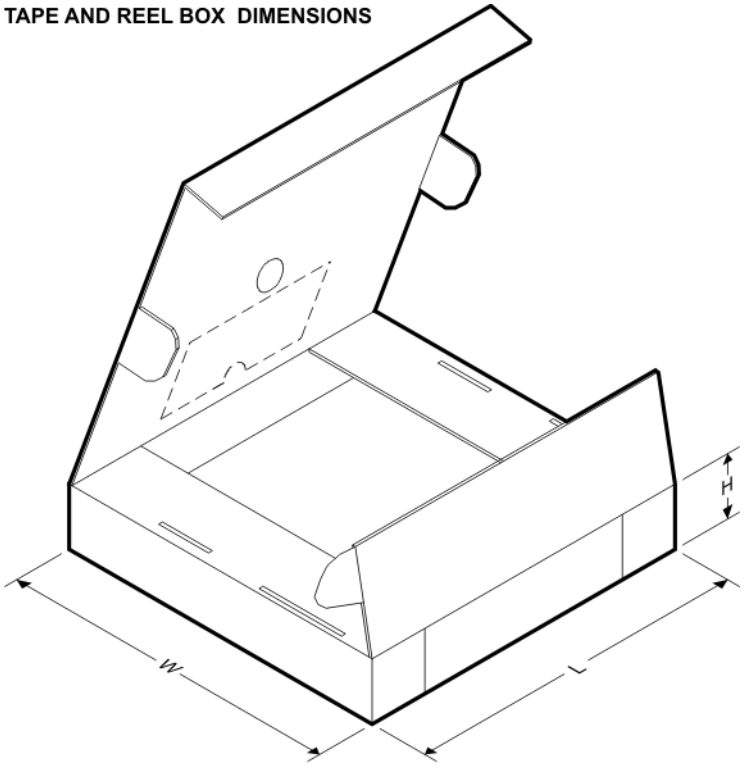


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LM2678SD-12	VSON	NHM	14	250	178.0	16.4	5.3	6.3	1.5	12.0	16.0	Q1
LM2678SD-12/NOPB	VSON	NHM	14	250	178.0	16.4	5.3	6.3	1.5	12.0	16.0	Q1
LM2678SD-3.3/NOPB	VSON	NHM	14	250	178.0	16.4	5.3	6.3	1.5	12.0	16.0	Q1
LM2678SD-5.0/NOPB	VSON	NHM	14	250	178.0	16.4	5.3	6.3	1.5	12.0	16.0	Q1
LM2678SD-ADJ	VSON	NHM	14	250	178.0	16.4	5.3	6.3	1.5	12.0	16.0	Q1
LM2678SD-ADJ/NOPB	VSON	NHM	14	250	178.0	16.4	5.3	6.3	1.5	12.0	16.0	Q1
LM2678SDX-3.3/NOPB	VSON	NHM	14	2500	330.0	16.4	5.3	6.3	1.5	12.0	16.0	Q1
LM2678SDX-5.0/NOPB	VSON	NHM	14	2500	330.0	16.4	5.3	6.3	1.5	12.0	16.0	Q1
LM2678SDX-ADJ/NOPB	VSON	NHM	14	2500	330.0	16.4	5.3	6.3	1.5	12.0	16.0	Q1
LM2678SX-12/NOPB	DDPAK/ TO-263	KTW	7	500	330.0	24.4	10.75	14.85	5.0	16.0	24.0	Q2
LM2678SX-3.3/NOPB	DDPAK/ TO-263	KTW	7	500	330.0	24.4	10.75	14.85	5.0	16.0	24.0	Q2
LM2678SX-5.0	DDPAK/ TO-263	KTW	7	500	330.0	24.4	10.75	14.85	5.0	16.0	24.0	Q2
LM2678SX-5.0/NOPB	DDPAK/ TO-263	KTW	7	500	330.0	24.4	10.75	14.85	5.0	16.0	24.0	Q2
LM2678SX-ADJ	DDPAK/ TO-263	KTW	7	500	330.0	24.4	10.75	14.85	5.0	16.0	24.0	Q2

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LM2678SX-ADJ/NOPB	DDPAK/ TO-263	KTW	7	500	330.0	24.4	10.75	14.85	5.0	16.0	24.0	Q2

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM2678SD-12	VSON	NHM	14	250	210.0	185.0	35.0
LM2678SD-12/NOPB	VSON	NHM	14	250	210.0	185.0	35.0
LM2678SD-3.3/NOPB	VSON	NHM	14	250	210.0	185.0	35.0
LM2678SD-5.0/NOPB	VSON	NHM	14	250	210.0	185.0	35.0
LM2678SD-ADJ	VSON	NHM	14	250	210.0	185.0	35.0
LM2678SD-ADJ/NOPB	VSON	NHM	14	250	210.0	185.0	35.0
LM2678SDX-3.3/NOPB	VSON	NHM	14	2500	367.0	367.0	35.0
LM2678SDX-5.0/NOPB	VSON	NHM	14	2500	367.0	367.0	35.0
LM2678SDX-ADJ/NOPB	VSON	NHM	14	2500	367.0	367.0	35.0
LM2678SX-12/NOPB	DDPAK/TO-263	KTW	7	500	367.0	367.0	45.0
LM2678SX-3.3/NOPB	DDPAK/TO-263	KTW	7	500	367.0	367.0	45.0
LM2678SX-5.0	DDPAK/TO-263	KTW	7	500	367.0	367.0	45.0
LM2678SX-5.0/NOPB	DDPAK/TO-263	KTW	7	500	367.0	367.0	45.0
LM2678SX-ADJ	DDPAK/TO-263	KTW	7	500	367.0	367.0	45.0
LM2678SX-ADJ/NOPB	DDPAK/TO-263	KTW	7	500	367.0	367.0	45.0

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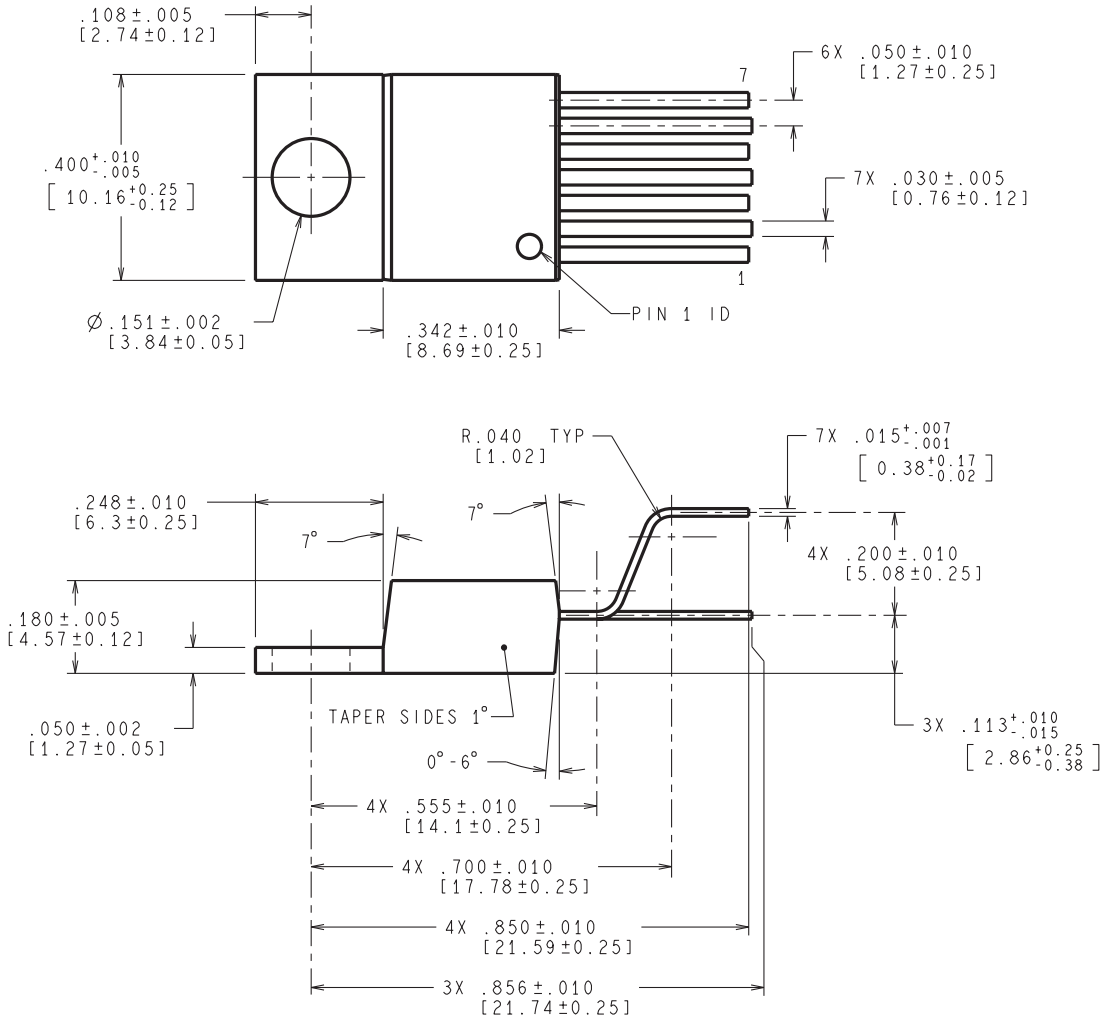

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TA07B (Rev E)

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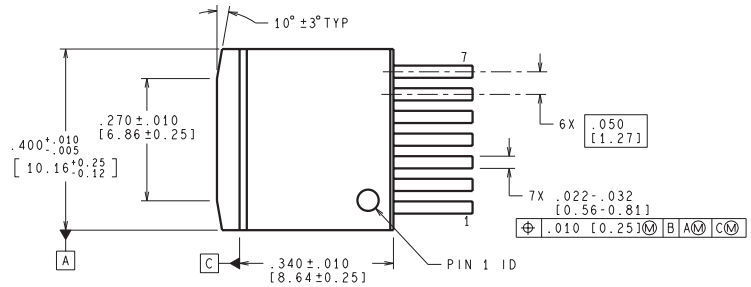
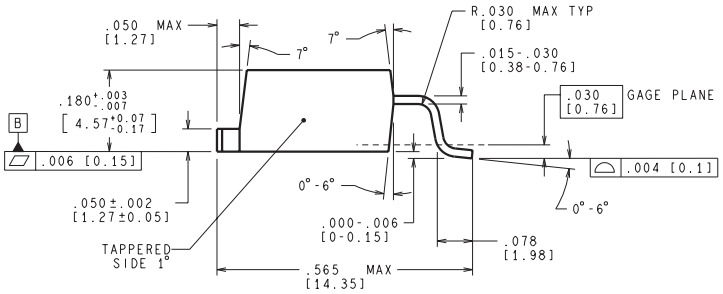
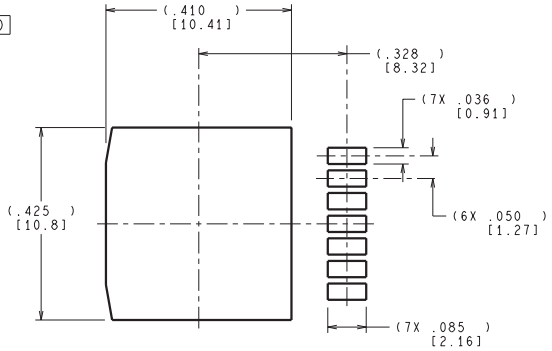
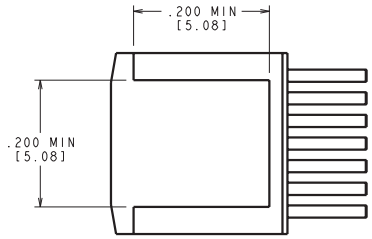






LAND PATTERN RECOMMENDATION



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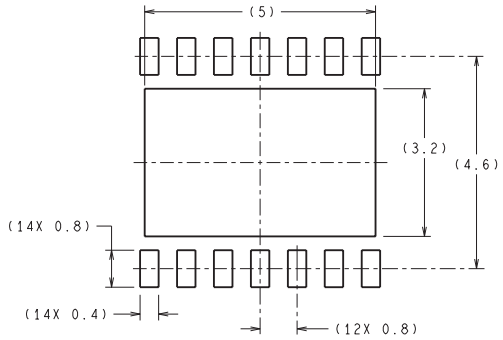
TS7B (Rev E)

NHM0014A



RECOMMENDED LAND PATTERN

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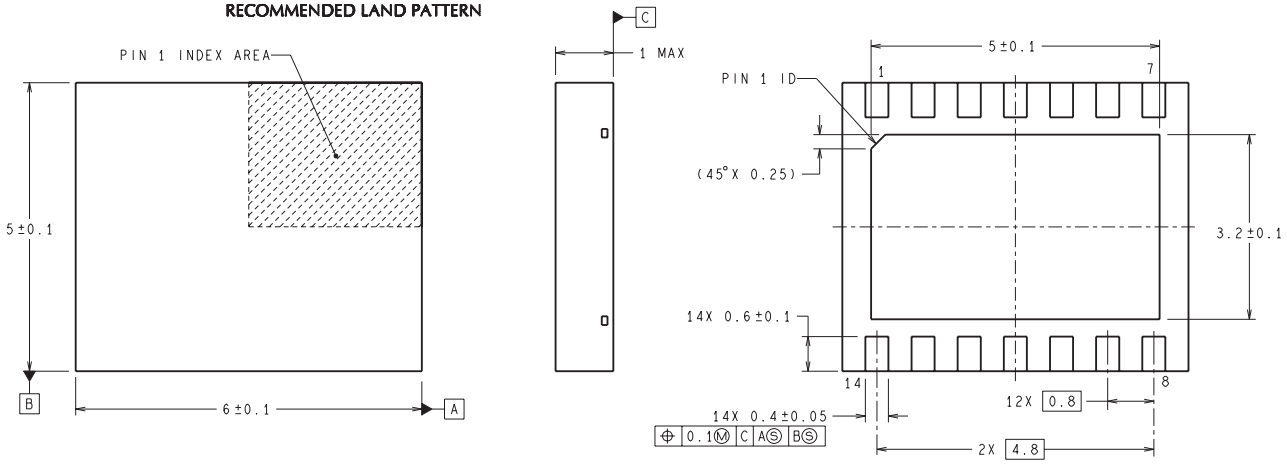

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Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

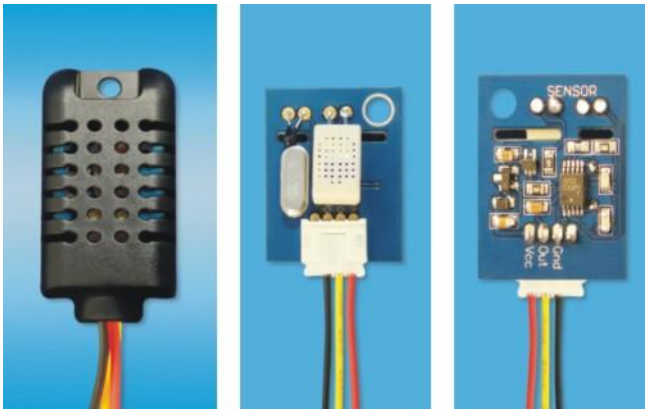
Appendix E

AM2301

AOSONG

Temperature and humidity module

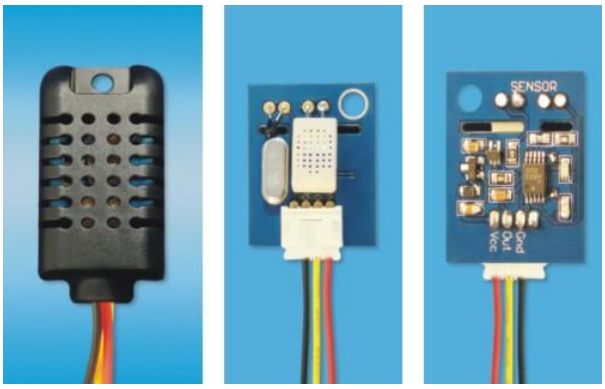
AM2301 Product Manual



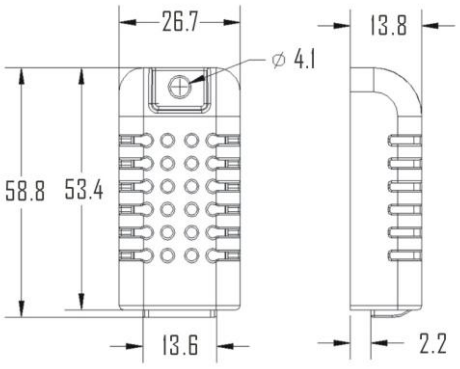
www.aosong.com

1、Product Overview

AM2301 capacitive humidity sensing digital temperature and humidity module is the one that contains the compound has been calibrated digital signal output of the temperature and humidity sensor. Application of a dedicated digital modules collection technology and the temperature and humidity sensing technology, to ensure that the product has high reliability and excellent long-term stability. The sensor includes a capacitive sensor wet components and a high-precision temperature measurement devices, and connected with a high-performance 8-bit microcontroller. The product has excellent quality, fast response, strong anti-jamming capability, and high cost. Each sensor is extremely accurate humidity calibration chamber calibration. The form of procedures, the calibration coefficients stored in the microcontroller, the sensor within the processing of the heartbeat to call these calibration coefficients. Standard single-bus interface, system integration quick and easy. Small size, low power consumption, signal transmission distance up to 20 meters, making it the best choice of all kinds of applications and even the most demanding applications. Products for the 3-lead (single-bus interface) connection convenience. Special packages according to user needs.



Physical map



Dimensions (unit: mm)

2、Applications

HVAC, dehumidifier, testing and inspection equipment, consumer goods, automotive, automatic control, data loggers, home appliances, humidity regulator, medical, weather stations, and other humidity measurement and control and so on.

3、Features

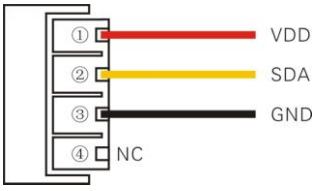
Ultra-low power, the transmission distance, fully automated calibration, the use of capacitive humidity sensor, completely interchangeable, standard digital single-bus output, excellent long-term stability, high accuracy temperature measurement devices.

4、The definition of single-bus interface

4.1 AM2301 Pin assignments

Table 1： AM2301 Pin assignments

Pin	Color	Name	Description
1	Red	VDD	Power (3.3V-5.2V)
2	Yellow	SDA	Serial data，Dual-port
3	Black	GND	Ground
4		NC	Empty



PIC1： AM2301 Pin Assignment

4.2 Power supply pins（VDD GND）

AM2301 supply voltage range 3.3V － 5.2V, recommended supply voltage is 5V.

4.3 Serial data（SDA）

SDA pin is tri structure for reading, writing sensor data. Specific communication timing, see the detailed description of the communication protocol.

5、Sensor performance

5.1 Relative humidity

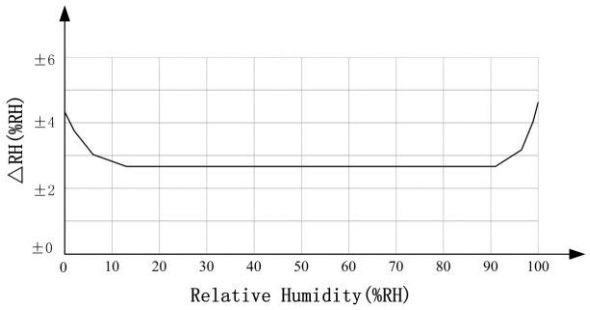
Table 2： AM2301 Relative humidity performance table

Parameter	Condition	min	typ	max	Unit
Resolution			0.1		%RH
Range		0		99.9	%RH
Accuracy [1]	25℃		± 3		%RH
Repeatability			± 1		%RH
Exchange		Completely interchangeable			
Response [2]	1/e(63%)		<6		S
Sluggish			± 0.3		%RH
Drift [3]	Typical		<0.5		%RH/yr

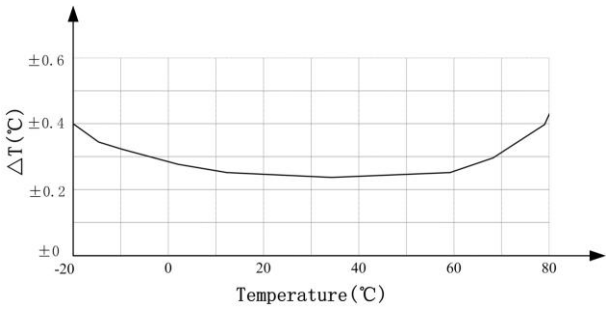
5.2 Temperature

Table 3： AM2301 Relative temperature performance

Parameter	Condition	min	typ	max	Unit
Resolution			0.1		℃
			16		bit
Accuracy			± 0.3	± 1	℃
Range		−40		80	℃
Repeat			± 0.2		℃
Exchange		Completely interchangeable			
Response	1/e(63%)		<10		S
Drift			± 0.3		℃/yr



Pic2: At25℃ The error of relative humidity



Pic3： The maximum temperature error

6、Electrical Characteristics

Electrical characteristics, such as energy consumption, high, low, input, output voltage, depending on the power supply. Table 4 details the electrical characteristics of the AM2301, if not identified, said supply voltage of 5V. To get the best results with the sensor, please design strictly in accordance with the conditions of design in Table 4.

Table 4： AM2301 DC Characteristics

Parameter	Condition	min	typ	max	Unit
Voltage		3.3	5	5.2	V
Power consumption [4]	Dormancy	10	15		μA
	Measuring		500		μA
	Average		300		μA
Low level output voltage	I_{OL} [5]	0		300	mV
High output voltage	Rp<25 kΩ	90%		100%	VDD
Low input voltage	Decline	0		30%	VDD
Input High Voltage	Rise	70%		100%	VDD
Rpu [6]	VDD = 5V VIN = VSS	30	45	60	kΩ
Output current	turn on		8		mA
	turn off	10	20		μA
Sampling period		2			S

[1] the accuracy of the factory inspection, the sensor 25 ° C and 5V, the accuracy specification of test conditions, it does not include hysteresis and nonlinearity, and is only suitable for non-condensing environment.

[2] to achieve an order of 63% of the time required under the conditions of 25 ℃ and 1m / s airflow.

[3] in the volatile organic compounds, the values may be higher. See the manual application to store information.

[4] this value at VDD = 5.0V when the temperature is 25 ℃, 2S / time, under the conditions of the average.

[5] low output current.

[6] that the pull-up resistor.

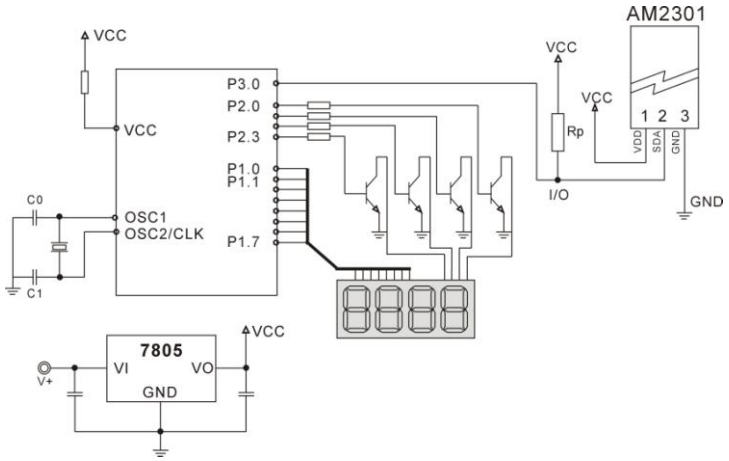
7、Single-bus communication（ONE-WIRE）

7.1 Typical circuits for single bus

Microprocessor and AM2301 connection typical application circuit is shown in Figure 4. Single bus communication mode, pull the SDA microprocessor I / O port is connected.

Special instructions of the single-bus communication：

1. Typical application circuit recommended in the short cable length of 30 meters on the 5.1K pull-up resistor pullup resistor according to the actual situation of lower than 30 m.
2. With 3.3V supply voltage, cable length shall not be greater than 100cm. Otherwise, the line voltage drop will lead to the sensor power supply, resulting in measurement error.
3. Read the sensor minimum time interval for the 2S; read interval is less than 2S, may cause the temperature and humidity are not allowed or communication is unsuccessful, etc..
4. Temperature and humidity values are each read out the results of the last measurement For real-time data that need continuous read twice, we recommend repeatedly to read sensors, and each read sensor interval is greater than 2 seconds to obtain accuratethe data.



Pic4： AM2301 Typical circuits for single bus

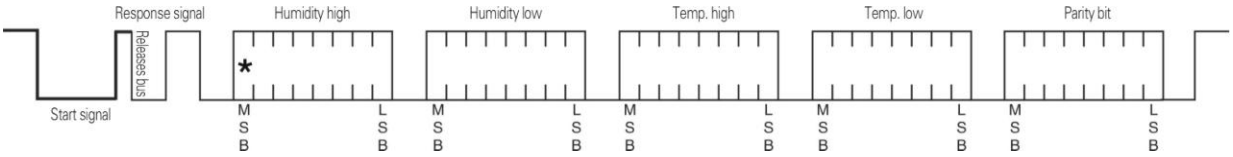
7.2、Single-bus communication protocol

◎Single bus Description

AM2301 device uses a simplified single-bus communication. Single bus that only one data line, data exchange system, controlled by the data line to complete. Equipment (microprocessor) through an open-drain or tri-state port connected to the data line to allow the device does not send data to release the bus, while other devices use the bus; single bus usually require an external about 5.1kΩ pull-up resistor, so when the bus is idle, its status is high. Because they are the master-slave structure, only the host calls the sensor, the sensor will answer, so the hosts to access the sensor must strictly follow the sequence of single bus, if there is a sequence of confusion, the sensor will not respond to the host.

◎Single bus to send data definition

SDA For communication and synchronization between the microprocessor and the AM2301, single-bus data format, a transmission of 40 data, the high first-out. Specific communication timing shown in Figure 5, the communication format is depicted in Table 5.



Pic5： AM2301 Single-bus communication protocol

Table 5： AM2301 Communication format specifier

Name	Single-bus format definition
Start signal	Microprocessor data bus (SDA) to bring down a period of time (at least 800μ s) [1] notify the sensor to prepare the data.
Response signal	Sensor data bus (SDA) is pulled down to 80μ s, followed by high-80μ s response to host the start signal.
Data format	Host the start signal is received, the sensor one-time string from the data bus (SDA) 40 data, the high first-out.
Humidity	Humidity resolution of 16Bit, the previous high; humidity sensor string value is 10 times the actual humidity values.
Temp.	Temperature resolution of 16Bit, the previous high; temperature sensor string value is 10 times the actual temperature value; The temperature is the highest bit (Bit15) is equal to 1 indicates a negative temperature, the temperature is the highest bit (Bit15) is equal to 0 indicates a positive temperature; Temperature in addition to the most significant bit (Bit14 ~ bit 0) temperature values.
Parity bit	Parity bit = humidity high + humidity low + temperature high + temperature low

◎**Single-bus data calculation example**

Example 1： 40 Data received：

0000 0010	1001 0010	0000 0001	0000 1101	1010 0010
High humidity 8	Low humidity 8	High temp. 8	Low temp. 8	Parity bit

Calculate：

0000 0010+1001 0010 +0000 0001+0000 1101= 1010 0010（Parity bit）

Received data is correct：

humidity： 0000 0010 1001 0010 = 0292H (Hexadecimal)= 2×256 + 9×16 + 2 = 658

=> Humidity = 65.8%RH

Temp.： 0000 0001 0000 1101 = 10DH(Hexadecimal) = 1×256 + 0×16 + 13 = 269

=> Temp.= 26.9℃

◎**Special Instructions：**

When the temperature is below 0 ℃, the highest position of the temperature data.

Example： −10.1 ℃ Expressed as 1 000 0000 0110 0101

Temp.： 0000 0000 0110 0101 = 0065H(Hexadecimal)= 6×16 +5 = 101

=> Temp. = −10.1℃

Example 2： 40 received data：

0000 0010	1001 0010	0000 0001	0000 1101	1011 0010
High humidity 8	Low humidity 8	High temp. 8	Low temp. 8	Parity bit

Calculate：

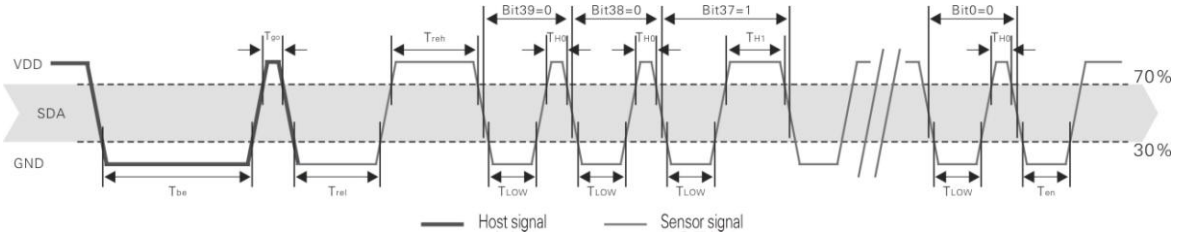
0000 0010+1001 0010 +0000 0001+0000 1101= 1010 0010 ≠ 1011 0010 （Validation error）

The received data is not correct, give up, to re-receive data.

7.3 Single-bus communication timing

User host (MCU) to send a start signal (data bus SDA line low for at least 800μ s) after AM2301 from Sleep mode conversion to high-speed mode.The host began to signal the end of the AM2301 send a response signal sent from the data bus SDA serial 40Bit's data, sends the byte high; data sent is followed by: Humidity high、Humidity low、Temperature high、Temperature low、Parity bit，Send data to the end of trigger information collection, the collection end of the sensor is automatically transferred to the sleep mode, the advent until the next communication.

Detailed timing signal characteristics in Table 6， Single-bus communication timing diagram Pic 6：



Pic 6： AM2301 Single-bus communication timing

Note: the temperature and humidity data read by the host from the AM2301 is always the last measured value, such as the two measurement interval is very long, continuous read twice to the second value of real-time temperature and humidity values, while two readtake minimum time interval be 2S.

Table 6: Single bus signal characteristics

Symbol	Parameter	min	typ	max	Unit
T_{be}	Host the start signal down time	0.8	1	20	mS
T_{go}	Bus master has released time	20	30	200	μS
T_{rel}	Response to low time	75	80	85	μS
T_{reh}	In response to high time	75	80	85	μS
T_{LOW}	Signal "0", "1" low time	48	50	55	μS
T_{H0}	Signal "0" high time	22	26	30	μS
T_{H1}	Signal "1" high time	68	70	75	μS
T_{en}	Sensor to release the bus time	45	50	55	μS

Note： To ensure the accurate communication of the sensor, the read signal, in strict accordance with the design parameters and timing in Table 6 and Figure 6.

7.4 Peripherals read step example

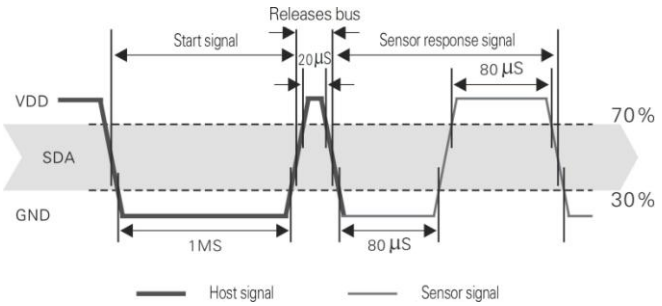
Communication between the host and the sensor can read data through the following three steps to complete.

Step 1

AM2301 have to wait for the power (on AM2301 power 2S crossed the unstable state, the device can not send any instructions to read during this period), the test environment temperature and humidity data, and record data, since the sensor into a sleep state automatically. AM2301 The SDA data line from the previous pull-up resistor pulled up is always high, the AM2301 the SDA pin is in input state, the time detection of external signal.

Step 2

Microprocessor I/O set to output, while output low, and low hold time can not be less than 800us, typical values are down 1MS, then the microprocessor I/O is set to input state, the release of the bus, due to the pull-up resistor, the microprocessor I/O AM2301 the SDA data line also will be high, the bus master has released the AM2301 send a response signal, that is, the output 80 microseconds low as the response signal, tightthen output high of 80 microseconds notice peripheral is ready to receive data signal transmission as shown to Pic7 :



Pic7： Single bus decomposition of the timing diagram

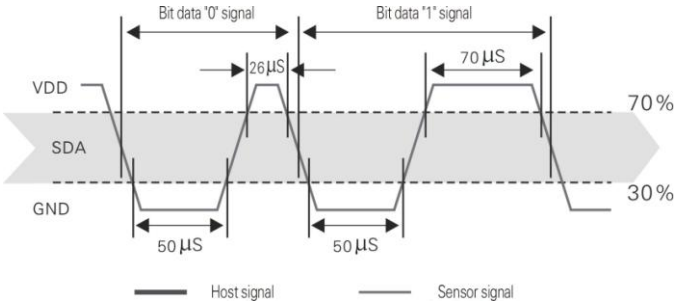
Step 3

AM2301 sending the response, followed by the data bus SDA continuous serial output 40 data, the microprocessor receives 40 data I/O level changes.

Bit data "0" format: 26-28 microseconds 50 microseconds low plus high;

Bit data "1" format: the high level of low plus, 50 microseconds to 70 microseconds;

Bit data "0" bit data "1" format signal shown to pic 8:

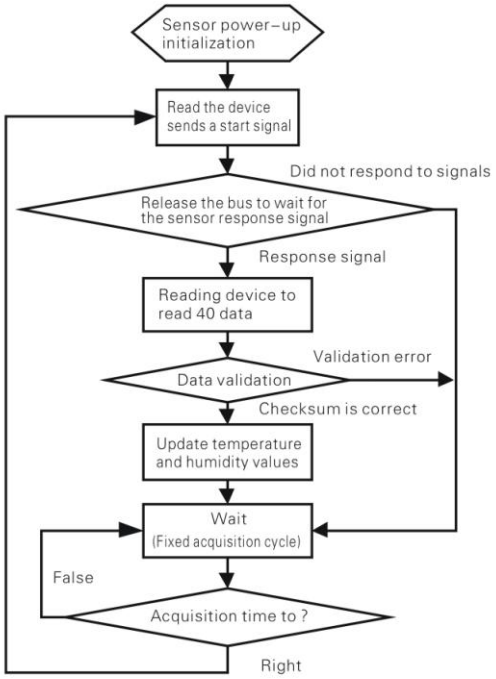


Pic 8： The single bus break down the timing diagram

AM2301 data bus SDA output 40 data continue to output the low 50 microseconds into the input state, followed by pull-up resistor goes high. AM2301 internal re-test environmental temperature and humidity data, and record the data, the end of the test records, the microcontroller automatically into hibernation. Microcontroller only after receipt of the start signal of the host wake-up sensor, into the working state.

7.5 Peripheral to read flow chart

AM2301 sensor read single bus flow chart diagram shown in Figure 9, we also provide the C51 read the code examples, customers need to download, please visit our website (www.aosong.com) related to downloadthis manual does not provide the code description.



Pic9：Single-bus to read the flow chart

8、Application of information

1. Work and storage conditions

Outside the sensor the proposed scope of work may lead to temporary drift of the signal up to 300%RH. Return to normal working conditions, sensor calibration status will slowly toward recovery. To speed up the recovery process may refer to "resume processing". Prolonged use of non-normal operating conditions, will accelerate the aging of the product.

Avoid placing the components on the long-term condensation and dry environment, as well as the following environment.

A, salt spray

B, acidic or oxidizing gases such as sulfur dioxide, hydrochloric acid

Recommended storage environment

Temperature: 10 ~ 40℃ Humidity: 60%RH or less

2. The impact of exposure to chemicals

The capacitive humidity sensor has a layer by chemical vapor interference, the proliferation of chemicals in the sensing layer may lead to drift and decreased sensitivity of the measured values. In a pure environment, contaminants will slowly be released. Resume processing as described below will accelerate this process. The high concentration of chemical pollution (such as ethanol) will lead to the complete damage of the sensitive layer of the sensor.

3. The temperature influence

Relative humidity of the gas to a large extent dependent on temperature. Therefore, in the measurement of humidity,

should be to ensure that the work of the humidity sensor at the same temperature. With the release of heat of electronic components share a printed circuit board, the installation should be as far as possible the sensor away from the electronic components and mounted below the heat source, while maintaining good ventilation of the enclosure. To reduce the thermal conductivity sensor and printed circuit board copper plating should be the smallest possible, and leaving a gap between the two.

4. Light impact

Prolonged exposure to sunlight or strong ultraviolet radiation, and degrade performance.

5. Resume processing

Placed under extreme working conditions or chemical vapor sensor, which allows it to return to the status of calibration by the following handler. Maintain two hours in the humidity conditions of 45℃ and <10% RH (dry); followed by 20-30℃ and> 70%RH humidity conditions to maintain more than five hours.

6. Wiring precautions

The quality of the signal wire will affect the quality of the voltage output, it is recommended to use high quality shielded cable.

7. Welding information

Manual welding, in the maximum temperature of 300℃ under the conditions of contact time shall be less than 3 seconds.

8. Product upgrades

Details, please the consultation Aosong electronics department.

9、The license agreement

Without the prior written permission of the copyright holder, shall not in any form or by any means, electronic or mechanical (including photocopying), copy any part of this manual, nor shall its contents be communicated to a third party. The contents are subject to change without notice.

The Company and third parties have ownership of the software, the user may use only signed a contract or software license.

10、Warnings and personal injury

This product is not applied to the safety or emergency stop devices, as well as the failure of the product may result in injury to any other application, unless a particular purpose or use authorized. Installation, handling, use or maintenance of the product refer to product data sheets and application notes. Failure to comply with this recommendation may result in death and serious personal injury. The Company will bear all damages resulting personal injury or death, and waive any claims that the resulting subsidiary company managers and employees and agents, distributors, etc. that may arise, including: a variety of costs, compensation costs, attorneys' fees, and so on.

11、Quality Assurance

The company and its direct purchaser of the product quality guarantee period of three months (from the date of delivery). Publishes the technical specifications of the product data sheet shall prevail. Within the warranty period, the product was confirmed that the quality is really defective, the company will provide free repair or replacement. The user must satisfy the following conditions:

① The product is found defective within 14 days written notice to the Company;

② The product shall be paid by mail back to the company;

③ The product should be within the warranty period.

The Company is only responsible for those used in the occasion of the technical condition of the product defective product. Without any guarantee, warranty or written statement of its products used in special applications. Company for its products applied to the reliability of the product or circuit does not make any commitment.

Appendix F

HC-SR04

Ultrasonic Ranging Module HC - SR04

Product features:

Ultrasonic ranging module HC - SR04 provides 2cm - 400cm non-contact measurement function, the ranging accuracy can reach to 3mm. The modules includes ultrasonic transmitters, receiver and control circuit. The basic principle of work:
(1) Using IO trigger for at least 10us high level signal,
(2) The Module automatically sends eight 40 kHz and detect whether there is a pulse signal back.
(3) IF the signal back, through high level , time of high output IO duration is the time from sending ultrasonic to returning.
Test distance = (high level time×velocity of sound (340M/S) / 2,

Wire connecting direct as following:

- 5V Supply
- Trigger Pulse Input
- Echo Pulse Output
- 0V Ground

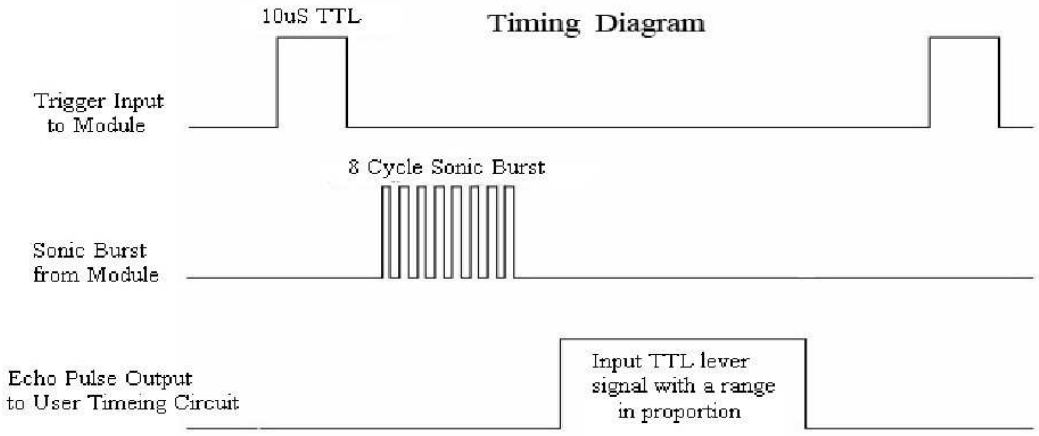
Electric Parameter

Working Voltage	**DC 5 V**
Working Current	**15mA**
Working Frequency	**40Hz**
Max Range	**4m**
Min Range	**2cm**
MeasuringAngle	**15 degree**
Trigger Input Signal	**10uS TTL pulse**
Echo Output Signal	**Input TTL lever signal and the range in proportion**
Dimension	**45*20*15mm**

Vcc Trig Echo GND

Timing diagram

The Timing diagram is shown below. You only need to supply a short 10uS pulse to the trigger input to start the ranging, and then the module will send out an 8 cycle burst of ultrasound at 40 kHz and raise its echo. The Echo is a distance object that is pulse width and the range in proportion .You can calculate the range through the time interval between sending trigger signal and receiving echo signal. Formula: uS / 58 = centimeters or uS / 148 =inch; or: the range = high level time * velocity (340M/S) / 2; we suggest to use over 60ms measurement cycle, in order to prevent trigger signal to the echo signal.



Attention:

- The module is not suggested to connect directly to electric, if connected electric, the GND terminal should be connected the module first, otherwise, it will affect the normal work of the module.
- When tested objects, the range of area is not less than 0.5 square meters and the plane requests as smooth as possible, otherwise ,it will affect the results of measuring.

www.Elecfreaks.com

Appendix G

Uxcell Hall Effect Flow Sensor

6mm Dia. Hall Effect Water Flow Sensor Switch Flowmeter Fluid Meter 0.3-4.5L/min

Market Price: $13.99 **Our Price: hello $5.99**

Model Number : a16080500ux0400

Descriptions:

1. The Water Flow Sensor is light, nimble outline, small size and easy to install. The bearings used in the rotating part. All materials are in line with ROHS testing standards.
2. There is an integrated hall effect sensor that outputs an electrical pulse with every revolution. The hall effect sensor is sealed from the water pipe and allows the sensor to stay safe and dry.
3. Three wire connection: Red for positive, black for negative, yellow for pulse signal.
4.The cumulative flow pulse conversion ratio 1L WATER=1146pulse+/-10%

Flow	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.5	L/min
Pulse	4.7	6.5	8.2	9.8	11.5	13.9	15.6	17.4	20.9	26.7	Hz
Flow	2.0	2.5	3.0	3.5	4	4.5					L/min
Pulse	36.2	47	55.6	65.2	75.8	88.3					Hz

Specifications:

Product Name: Water Flow Sensor
Material: Plastic(Shell)
Liquid Temperature: Not More Than 60C
Working Voltage Range: DC 4.5V~18V
Rated Voltage: DC 5V
Max Current: 10mA(DC 5V)
Maximum water pressure: 0.8MPa
Flow Range: 0.3-4.5L/min
Connector Tube Dia.: 6mm
Connector: Male XH-3P Plug
Cable Length: 33cm
Size: 86mm x 40mm x 22mm(L*W*H)
Color: White
Net Weight: 31g

Package Included:

1 x Water Flow Sensor

Country of Manufacture	CHINA
Material	Plastic(Shell)
Net Weight	31g
Package Content	1 x Water Flow Sensor
Main Color	White
Product Name	Water Flow Sensor

This product was added to our catalog on Tuesday 06 September, 2016.

Customer Reviews Add to Cart

Write a review for **6mm Dia. Hall Effect Water Flow Sensor Switch Flowmeter Fluid Meter 0.3-4.5L/min**

NOTE: HTML is not translated!

Your name:

Your email address:

Security code: 9 k x j t

Rating: BAD GOOD

Submit

Appendix H

SEN0161 pH Meter

PH meter(SKU: SEN0161)

From Robot Wiki

Contents

Analog pH Meter Kit

Introduction

Need to measure water quality and other parameters but haven't got any low cost pH meter? Find it difficult to use with Arduino?
Here comes an analog pH meter, specially designed for Arduino controllers and has built-in simple, convenient and practical connection and features. It has an LED which works as the Power Indicator, a BNC connector and PH2.0 sensor interface. To use it, just connect the pH sensor with BNC connector, and plug the PH2.0 interface into the analog input port of any Arduino controller. If pre-programmed, you will get the pH value easily. Comes in compact plastic box with foams for better mobile storage.
Attention:In order to ensure the accuracy of the pH probe, you need to use the standard solution to calibrate it regularly.Generally, the period is about half a year. If you meaure the dirty aqueous solution, you need to increase the frequency of calibration.

Applications

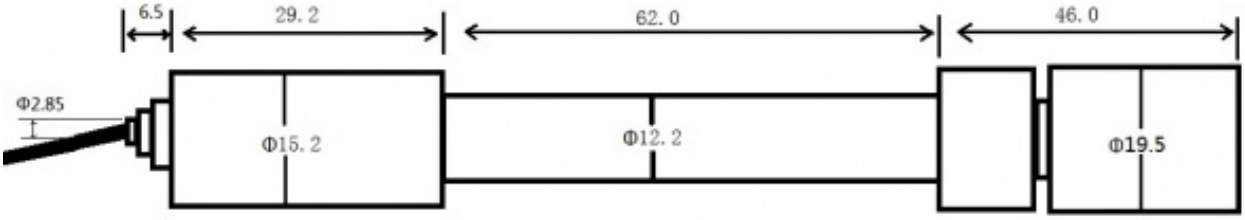
- Water quality testing
- Aquaculture

Specification

- Module Power : 5.00V
- Module Size : 43mm×32mm
- Measuring Range:0-14PH
- Measuring Temperature :0-60 ℃

- Accuracy : ± 0.1pH (25 ℃)
- Response Time : ≤ 1min
- pH Sensor with BNC Connector
- PH2.0 Interface (3 foot patch)
- Gain Adjustment Potentiometer
- Power Indicator LED
- Cable Length from sensor to BNC connector:660mm

pH Electrode Size



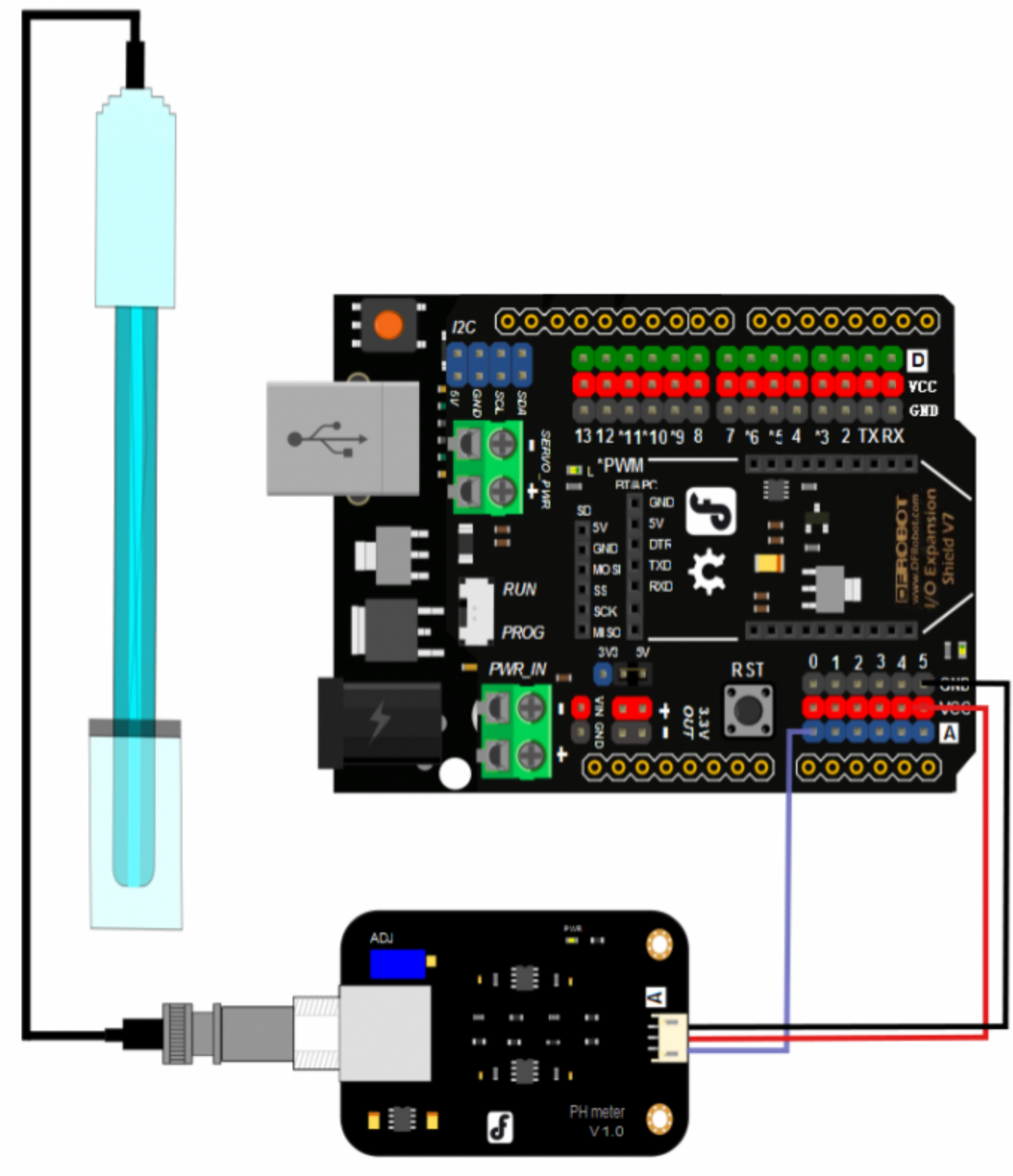
pH Electrode Characteristics

The output of pH electrode is Millivolts,and the pH value of the relationship is shown as follows (25 ℃):

VOLTAGE （mV）	pH value	VOLTAGE （mV）	pH value
414.12	0.00	-414.12	14.00
354.96	1.00	-354.96	13.00
295.80	2.00	-295.80	12.00
236.64	3.00	-236.64	11.00
177.48	4.00	-177.48	10.00
118.32	5.00	-118.32	9.00
59.16	6.00	-59.16	8.00
0.00	7.00	0.00	7.00

Use the pH Meter

Connecting Diagram



Step to Use the pH Meter

Cautions:

- Please use an external switching power supply,and the voltage as close as possible to the +5.00V. More accurate the voltage, more higher the accuracy!

- Before the electrode in continuous use every time,you need to calibrate it by the standard solution,in order to obtain more accurate results.The best environment temperature is about 25 ℃,and the pH value is known and reliable,close to the measured value. If you measure the acidic sample, the pH value of the standard solution should be 4.00.If you measure the alkaline sample, the pH value of the standard solution should be 9.18.Subsection calibration, just in order to get a better accuracy.
- Before the pH electrode measured different solutions, we need to use water to wash it. We recommend using deionized water.

(1) Connect equipments according to the graphic,that is,the pH electrode is connected to the BNC connector on the pH meter board， and then use the connection lines,the pH meter board is connected to the ananlong port 0 of the Arduino controller. When the Arduino controller gets power,you will see the blue LED on board is on.
(2) Upload the sample code to the Arduino controller.
(3) Put the pH electrode into the standard solution whose pH value is 7.00， or directly shorted the input of the BNC connector.Open the serial monitor of the Arduino IDE,you can see the pH value printed on it,and the error does not exceed 0.3. Record the pH value printed,then compared with 7.00, and the difference should be changed into the "Offset" in the sample code. For example,the pH value printed is 6.88,so the difference is 0.12.You should change the "# define Offset 0.00" into "# define Offset 0.12" in your program.
(4) Put the pH electrode into the pH standard solution whose value is 4.00.Then wait about one minute,adjust the gain potential device, let the value stabilise at around 4.00.At this time,the acidic calibration has been completed and you can measure the pH value of an acidic solution.
Note:If you want to measure the pH value of other solution,you must wash the pH electrode first!
(5) According to the linear characteristics of pH electrode itself, after the above calibration,you can directly measure the pH value of the alkaline solution, but if you want to get better accuracy, you can recalibrate it. Alkaline calibration use the standard solution whose pH value is 9.18.Also adjust the gain potential device, let the value stabilise at around 9.18. After this calibration, you can measure the pH value of the alkaline solution.

Sample Code

Sample code for testing the PH meter and get the sensor feedback from the Arduino Serial Monitor.

```
/*
 # This sample code is used to test the pH meter V1.0.
 # Editor : YouYou
 # Ver    : 1.0
 # Product: analog pH meter
 # SKU    : SEN0161
*/
#define SensorPin A0            //pH meter Analog output to Arduino Analog Input 0
#define Offset 0.00            //deviation compensate
#define LED 13
#define samplingInterval 20
#define printInterval 800
#define ArrayLenth  40    //times of collection
int pHArray[ArrayLenth];   //Store the average value of the sensor feedback
int pHArrayIndex=0;
void setup(void)
{
  pinMode(LED,OUTPUT);
  Serial.begin(9600);
  Serial.println("pH meter experiment!");    //Test the serial monitor
}
void loop(void)
```

```
{
  static unsigned long samplingTime = millis();
  static unsigned long printTime = millis();
  static float pHValue,voltage;
  if(millis()-samplingTime > samplingInterval)
  {
      pHArray[pHArrayIndex++]=analogRead(SensorPin);
      if(pHArrayIndex==ArrayLenth)pHArrayIndex=0;
      voltage = avergearray(pHArray, ArrayLenth)*5.0/1024;
      pHValue = 3.5*voltage+Offset;
      samplingTime=millis();
  }
  if(millis() - printTime > printInterval)   //Every 800 milliseconds, print a numerical, convert the state of the LED
  {
        Serial.print("Voltage:");
        Serial.print(voltage,2);
        Serial.print("    pH value: ");
        Serial.println(pHValue,2);
        digitalWrite(LED,digitalRead(LED)^1);
        printTime=millis();
  }
}
double avergearray(int* arr, int number){
  int i;
  int max,min;
  double avg;
  long amount=0;
  if(number<=0){
    Serial.println("Error number for the array to avraging!/n");
    return 0;
  }
  if(number<5){   //less than 5, calculated directly statistics
    for(i=0;i<number;i++){
      amount+=arr[i];
    }
    avg = amount/number;
    return avg;
  }else{
    if(arr[0]<arr[1]){
      min = arr[0];max=arr[1];
    }
    else{
      min=arr[1];max=arr[0];
    }
    for(i=2;i<number;i++){
      if(arr[i]<min){
        amount+=min;        //arr<min
        min=arr[i];
      }else {
        if(arr[i]>max){
          amount+=max;    //arr>max
          max=arr[i];
        }else{
          amount+=arr[i]; //min<=arr<=max
        }
      }//if
    }//for
    avg = (double)amount/(number-2);
  }//if
  return avg;
}
```

Precautions

- The electrode used for the first or long set without re-use, the electrode bulb and the sand core, immersed in the 3NKCL solution activated eight hours.
- The electrode plug should be kept clean and dry.
- Electrode reference solution is the 3NKCL solution.
- Measurement should be avoided staggered pollution between solutions, so as not to affect the accuracy of measurement.
- Electrode blub or sand core is defiled which will make PTS decline, slow response. So, it should be based on the characteristics of the pollutant, adapted to the cleaning solution, the electrode performance recovery.
- The electrode should not be long-term immersed in acid chloride solution.
- Electrode when in use, the ceramic sand core and liquid outlet rubber ring should be removed, in order to make salt bridge solution to maintain a certain velocity.

Documents

Schematic (http://www.dfrobot.com/image/data/SEN0161/pH%20meter%20V1.0%20SCH.pdf)
PCB Design layout (http://www.dfrobot.com/image/data/SEN0161/ph%20meter%20V1.0%20layout.pdf)
pH Electrode Manual
(http://www.dfrobot.com/image/data/SEN0161/PH%20composite%20electrode%20manual.pdf)
Arduino Sample Code (http://www.dfrobot.com/image/data/SEN0161/phMeterSample.zip)
Zips For All Above (http://www.dfrobot.com/image/data/SEN0161/DFRobot%20SEN0161.zip)

Appendix I

DFR0300 Analog EC Meter

Analog EC Meter SKU:DFR0300

Contents

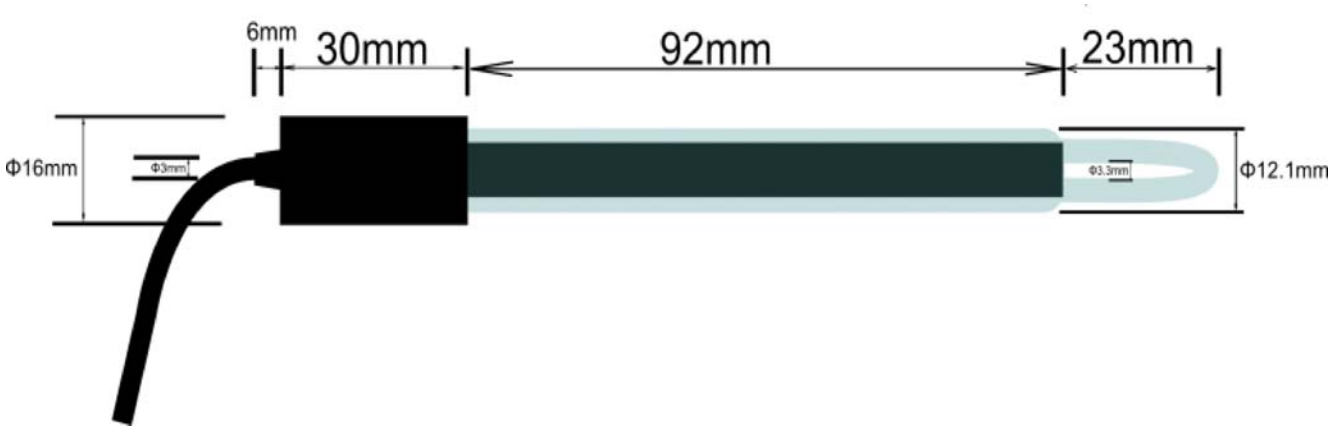
Introduction

- Want to DIY an EC meter? Need to measure the conductivity value? Find it difficult to use with Arduino? Don't understand conductivity? Here comes an analog EC meter,specially designed for **Arduino controllers** (https://www.dfrobot.com/category-104.html) and has built-in simple, convenient and practical connection and features.When done the connection according to the diagram ,then with the program control,it's very convenient to measure the conductivity value.
- Conductivity is the ability of substance to carry the current. It is the reciprocal of resistivity. In liquid, we often use the reciprocal of resistance, that is conductance, to measure the conductive capacity. The conductivity of water is a important indicator in the measurement of water quality. It can reflect the level of electrolytes present in the water. Depending on the concentration of the electrolyte, the conductivity of the aqueous solution is different.
- In the International System of Units, the uint of conductivity is Siemens / meter (S/m), and the other units are: S/m, mS/cm, μS/cm. Conversion relationship is: 1S/m = 1000mS/m = 1000000μS/m = 10mS/cm = 10000μS/cm.

Specification

- Operating Voltage: +5.00 V
- PCB Size: 45mm × 32mm
- Measuring Range: 1ms/cm–20ms/cm
- Operating Temperature :5-40 ℃
- Accuracy: <±10% F.S (specific accuracy depends on the accuracy of your calibration solution)
- PH2.0 Interface (3-pin SMD)
- Conductivity Electrode (Electrode Constant K = 1,BNC connector)
- Cable Length of the Electrode: about 60cm
- DS18B20 Temperature Sensor(Waterproof)
- Power Indicator

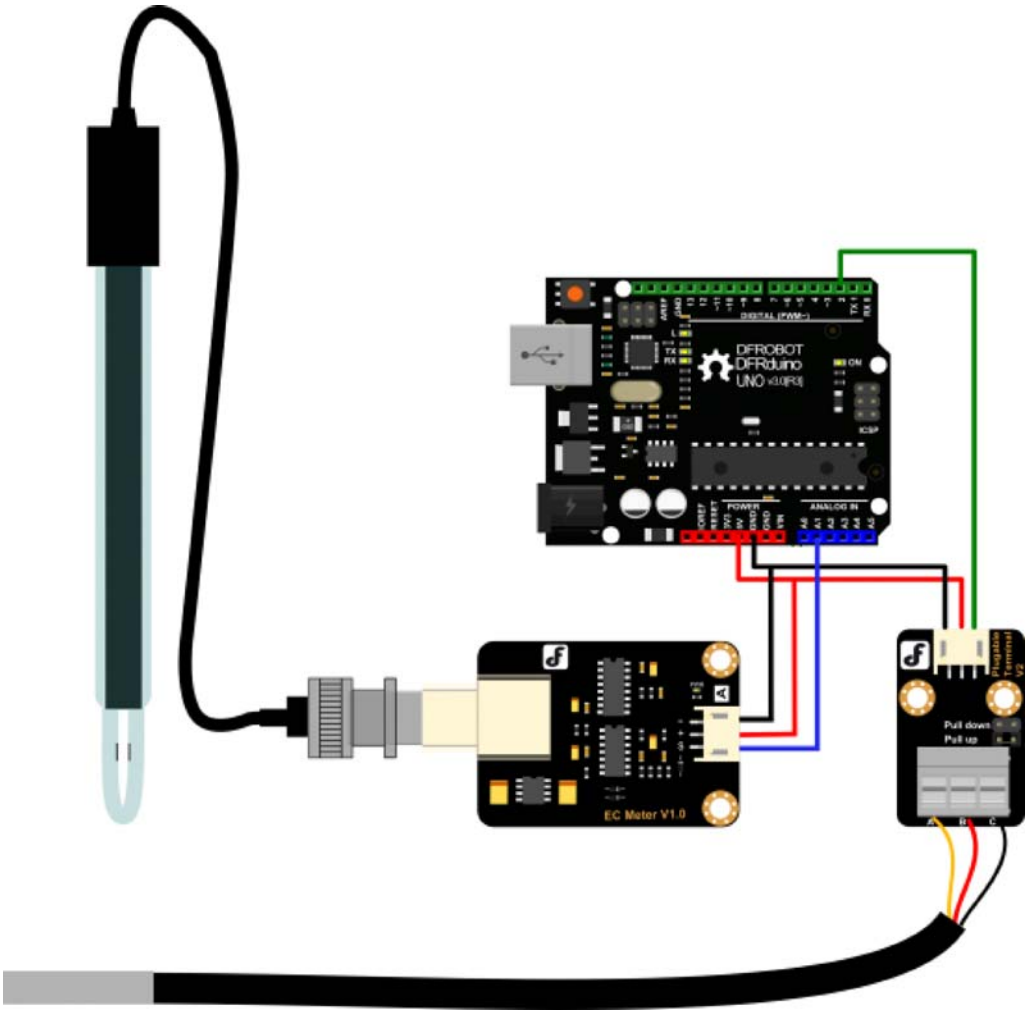
Electrode Size



(/wiki/index.php/File:EC_size.png)

Use the EC Meter(Elementary)

Connecting Diagram



(/wiki/index.php/File:EC_Meter_Sys.png)

Step to Use the EC Meter

Cautions

- Please use an external stable power supply(such as 7.5V DC),and the voltage of MCU system as close as possible to the +5.00V. More accurate the voltage, higher the accuracy!
- Before measuring a different solution, you need to use water to wash the conductivity electrode and temperature sensor,in order to prevent contamination and inaccurate result. The deionized water is recommended to wash the electrode and sensor.
- When measuring the conductivity of the solution, make sure that the temperature sensor is inserted into the test solution first. You should use the conductivity electrode to stir the solution. This will let the conductive portion of the electrode have a full contact with the solution. When the temperature and conductivity value is stable, you can read the required value.
- Affected by the polarization, we will get some conductivity values jittered when we measure high conductivity solution. The higher the conductivity, the more powerful values jittered.

NOTE:

- **Long-firing Operation**: Sampling test method was used to test the EC value, dont support to immerse into solution for a long time, so please take out the electrode from solution after testing
- **Life Span**: In 25 ℃, pure water,PH 6-8, it can work about one year, and just for reference, if put it in turbid, strongly acid and alkali solution, 25℃, the life span would drop to half a year even less time. The life span depends on your using environment.

STEPS

1. Connect equipments according to the connecting diagram, that is, the conductivity electrode is connected to the BNC connector on the EC meter board, and then use the analog connection line, the EC meter board is connected to the anlong pin 1 of the Arduino controller. The temperature sensor is connected to the connecting terminal of the terminal sensor adapter. Then you should use the digital connection line, the terminal sensor adapter is connected to the digital pin2 of the Arduino controller. When the Arduino controller (https://www.dfrobot.com/category-104.html) gets power,you will see the blue LED on board is on.
2. Upload the sample code to the Arduino controller.
3. Open the serial monitor of the Arduino IDE, you will see some information such as temperature, voltage, conductivity and so on. If you don't put the electorde in the solution, you will see "No solution!"

```
Analog value:0    Voltage:0mV    temp:26.37^C    EC:No solution!
Analog value:0    Voltage:0mV    temp:26.37^C    EC:No solution!
Analog value:0    Voltage:0mV    temp:26.37^C    EC:No solution!
Analog value:0    Voltage:0mV    temp:26.37^C    EC:No solution!
Analog value:0    Voltage:0mV    temp:26.31^C    EC:No solution!
```

(/wiki/index.php/File:20140408120155.jpg)
step 3

4. Put the conductivity electrode and temperature sensor into the calibration solution, stir the solution for some time and wait for the stable readings. If the conductivity reading on the serial monitor is close to the solution's conductivity, you can apply it in your project now.

   e.g. The conductivity of the solution is 1413us/cm.

```
Analog value:43    Voltage:209mV    temp:23.19'C    EC:1.41ms/cm
Analog value:43    Voltage:209mV    temp:23.19'C    EC:1.41ms/cm
Analog value:43    Voltage:209mV    temp:23.19'C    EC:1.41ms/cm
Analog value:43    Voltage:209mV    temp:23.19'C    EC:1.41ms/cm
Analog value:43    Voltage:209mV    temp:23.19'C    EC:1.41ms/cm
```

(/wiki/index.php/File:20140408120506.jpg)‘

Sample Code

Firstly, please install the library OneWire (http://www.pjrc.com/teensy/arduino_libraries/OneWire.zip).

```
// #
// # Editor     : YouYou from DFRobot
// # Date       : 23.04.2014
// # E-Mail : youyou.yu@dfrobot.com

// # Product name: Analog EC Meter
// # Product SKU : DFR0300
// # Version     : 1.0

// # Description:
// # Sample code for testing the EC meter and get the data feedback from the Arduino Serial Monito

// # Connection:
// #        EC meter output     -> Analog pin 1
// #        DS18B20 digital pin -> Digital pin 2
// #

#include <OneWire.h>

#define StartConvert 0
#define ReadTemperature 1

const byte numReadings = 20;     //the number of sample times
byte ECsensorPin = A1;  //EC Meter analog output,pin on analog 1
byte DS18B20_Pin = 2; //DS18B20 signal, pin on digital 2
unsigned int AnalogSampleInterval=25,printInterval=700,tempSampleInterval=850;  //analog sample in
unsigned int readings[numReadings];      // the readings from the analog input
byte index = 0;                  // the index of the current reading
unsigned long AnalogValueTotal = 0;                  // the running total
unsigned int AnalogAverage = 0,averageVoltage=0;                // the average
unsigned long AnalogSampleTime,printTime,tempSampleTime;
float temperature,ECcurrent;

//Temperature chip i/o
OneWire ds(DS18B20_Pin);  // on digital pin 2

void setup() {
 // initialize serial communication with computer:
  Serial.begin(115200);
  // initialize all the readings to 0:
  for (byte thisReading = 0; thisReading < numReadings; thisReading++)
    readings[thisReading] = 0;
  TempProcess(StartConvert);   //let the DS18B20 start the convert
  AnalogSampleTime=millis();
  printTime=millis();
  tempSampleTime=millis();
}

void loop() {
  /*
   Every once in a while,sample the analog value and calculate the average.
  */
  if(millis()-AnalogSampleTime>=AnalogSampleInterval)
  {
    AnalogSampleTime=millis();
     // subtract the last reading:
    AnalogValueTotal = AnalogValueTotal - readings[index];
```

```
    // read from the sensor:
    readings[index] = analogRead(ECsensorPin);
    // add the reading to the total:
    AnalogValueTotal = AnalogValueTotal + readings[index];
    // advance to the next position in the array:
    index = index + 1;
    // if we're at the end of the array...
    if (index >= numReadings)
    // ...wrap around to the beginning:
    index = 0;
    // calculate the average:
    AnalogAverage = AnalogValueTotal / numReadings;
  }
  /*
   Every once in a while,MCU read the temperature from the DS18B20 and then let the DS18B20 start
   Attention:The interval between start the convert and read the temperature should be greater tha
  */
   if(millis()-tempSampleTime>=tempSampleInterval)
  {
    tempSampleTime=millis();
    temperature = TempProcess(ReadTemperature);  // read the current temperature from the  DS18B20
    TempProcess(StartConvert);                   //after the reading,start the convert for next re
  }
   /*
   Every once in a while,print the information on the serial monitor.
  */
  if(millis()-printTime>=printInterval)
  {
    printTime=millis();
    averageVoltage=AnalogAverage*(float)5000/1024;
    Serial.print("Analog value:");
    Serial.print(AnalogAverage);   //analog average,from 0 to 1023
    Serial.print("    Voltage:");
    Serial.print(averageVoltage);  //millivolt average,from 0mv to 4995mV
    Serial.print("mV    ");
    Serial.print("temp:");
    Serial.print(temperature);    //current temperature
    Serial.print("^C     EC:");

    float TempCoefficient=1.0+0.0185*(temperature-25.0);    //temperature compensation formula: fF
    float CoefficientVolatge=(float)averageVoltage/TempCoefficient;
    if(CoefficientVolatge<150)Serial.println("No solution!");   //25^C 1413us/cm<-->about 216mv  i
    else if(CoefficientVolatge>3300)Serial.println("Out of the range!");  //>20ms/cm,out of the ra
    else
    {
      if(CoefficientVolatge<=448)ECcurrent=6.84*CoefficientVolatge-64.32;   //1ms/cm<EC<=3ms/cm
      else if(CoefficientVolatge<=1457)ECcurrent=6.98*CoefficientVolatge-127;  //3ms/cm<EC<=10ms/c
      else ECcurrent=5.3*CoefficientVolatge+2278;                           //10ms/cm<EC<20ms/cm
      ECcurrent/=1000;    //convert us/cm to ms/cm
      Serial.print(ECcurrent,2);  //two decimal
      Serial.println("ms/cm");
    }
  }

}
/*
ch=0,let the DS18B20 start the convert;ch=1,MCU read the current temperature from the DS18B20.
*/
```

```
float TempProcess(bool ch)
{
  //returns the temperature from one DS18B20 in DEG Celsius
  static byte data[12];
  static byte addr[8];
  static float TemperatureSum;
  if(!ch){
          if ( !ds.search(addr)) {
              Serial.println("no more sensors on chain, reset search!");
              ds.reset_search();
              return 0;
          }
          if ( OneWire::crc8( addr, 7) != addr[7]) {
              Serial.println("CRC is not valid!");
              return 0;
          }
          if ( addr[0] != 0x10 && addr[0] != 0x28) {
              Serial.print("Device is not recognized!");
              return 0;
          }
          ds.reset();
          ds.select(addr);
          ds.write(0x44,1); // start conversion, with parasite power on at the end
  }
  else{
          byte present = ds.reset();
          ds.select(addr);
          ds.write(0xBE); // Read Scratchpad
          for (int i = 0; i < 9; i++) { // we need 9 bytes
            data[i] = ds.read();
          }
          ds.reset_search();
          byte MSB = data[1];
          byte LSB = data[0];
          float tempRead = ((MSB << 8) | LSB); //using two's compliment
          TemperatureSum = tempRead / 16;
    }
          return TemperatureSum;
}
```

Use the EC Meter(Advanced)

According to the above-mentioned steps, you can easily measure the conductivity between 1ms/cm to 20ms/cm. But the vessel constant of each electrode is different, so the accuracy is not very high. You need calibration. So the following will introduce the principle of measurement and scheme of calibration.

Principle of Measurement

Firstly, please open the schematic and find the chip U3B. It consists of the reverse scaled circuit. The transfer function is Vo=R10/R*Vi. R10 is a feedback resistance and it's value is 820ohm according to the schematic. R is the resisitance when the electrode inserted in aqueous solution. It's value is related to the conductivity of the aqueous solution. R10/R is called magnification. When the R is changed, the magnification is also changed, so the Vo changed.So Vo is related to R. On the right of the reverse scaled circuit, there is a absolute-value circuit. It's

transfer function is Vo=|vi|. Arduino samples the output of the absolute-value circuit to calculate conductivity. The following analyses the calibration principle.

Definition of resistance: $R = \rho \frac{L}{A}$ (/wiki/index.php/File:Dzdy.jpg)

ρ is the resistivity; L is the length of the resistor element; A is the cross section of a resistor.
For the conductivity electrode, L is the spacing between two conductive sheets, A is the area of the conductive sheet.

Definition of conductivity: $\kappa = \frac{1}{\rho}$ (/wiki/index.php/File:Dddy.jpg)

According to the above two equations, we can get this equation: $\kappa = \frac{1}{R} \bullet \frac{L}{A}$ (/wiki/index.php/File:Gxs.jpg)

1/R is called conduction G.L/A is called vessel constant Q.

The transfer function of the measurement circuit is: $Vout = \frac{R10}{R} \times |Vin|$ (/wiki/index.php/File:Transfer.jpg)

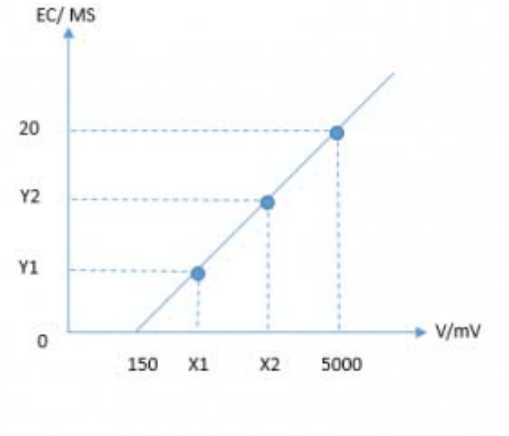
R is the resistance of the electrode when inserted into aqueous solution.

In conclusion, we can get this equation: $\kappa = \frac{Q}{R10 \bullet |Vin|} \times Vout$ (/wiki/index.php/File:Result.jpg)

Q is the vessel constant. It is a constant and different from each electrode. In the schematic, R10 is 820Ω.|Vin| is also a constant depend on the signal generating circuit. It's value is about 200mV. So we can see, the conductivity is linear with the output voltage.

Scheme of Calibration

1. Make your solution temperature be at 25℃
2. Do the wiring according to the above connecting diagram
3. Upload the sample code in the above section: Sample Code (http://www.dfrobot.com/wiki/index.php?



(/wiki/index.php/File:Co_.png)
For step4. The relationship between the analog reading and the EC

title=Analog_EC_Meter_SKU:DFR0300#Sample_Code)

4. Insert the probes (the conductivity electrode and the temperature sensor) into the solution A, e.g. the sample EC solution, 1413 uS/cm, and open the Arduino Serial monitor, you will read a average voltage, take it as V1. So the two numbers (V1, 1.413) composed to the first point **A** in the picture on the right:
(X1, Y1) = (V1, 1.413)
5. Take out the probes and clean it with pure water

6. Then submerge them again into another sample EC solution, 12.88ms/cm. read another average Voltage as V2. Now you get another point **B** in the above picture, namely: (X2, Y2) = (V2, 12.88)
7. With the two points (x1, y1) and (x2, y2), you can draw out the line to describe the relationship between the analog reading and the EC. Reading: how to draw out the line (https://www.mathsisfun.com/algebra/line-equation-2points.html)

This is how the three equations were calculated out using different EC solutions inbetween 1ms/cm ~ 3ms/cm ~ 10ms/cm ~ 20ms/cm in the sample code

```
1 if(CoefficientVolatge<=448)ECcurrent=6.84*CoefficientVolatge-64.32;   //1ms/cm<EC<=3ms/cm
2 else if(CoefficientVolatge<=1457)ECcurrent=6.98*CoefficientVolatge-127;  //3ms/cm<EC<=10ms/cm
3 else ECcurrent=5.3*CoefficientVolatge+2278;                           //10ms/cm<EC<20ms/cm
```

NOTE:

- This is a video about **EC Calibration** (https://www.youtube.com/watch?v=SfYD8JZ1wK4&feature=youtu.be)
- And you can get its code on **Github** (https://github.com/DFRobot/Analog-Electrical-Conductivity-Sensor).

Precautions

- There are two kinds of conductivity electrode, shiny electrode and platinum black electrode.platinum-plated black aims to increase the effective area of the electrode sheet and relieve being polarized. So in the measurement of large conductivity solutions, using a platinum black electrode is more appropriate.
- Platinum black electrode substrate surface attached loose platinum black layer, so it should be avoid touching any object and only rinsed with deionized water. Otherwise you will damage the platinum black layer, resulting in inaccurate measurement.
- If you found the performance of a platinum black electrode has decayed, you can use the ethanol and deionized water to wash the platinum sheet. This is very important in high-accuracy measurement.
- Platinum black electrode substrate surface attached loose platinum black layer,so in the measurement of samples, it is possible to adsorbe sample composition. After using the electrode, you must be timely to rinse the electrode.
- If you lay conductivity electrodes aside for some time, or use it for a period of time, the cell constant may change.If the accuracy requirements for measuring is relatively high, it is recommend that you should periodicly calibrate the cell constant according to the user manual of the instrument.

FAQ

Q1. Can you give me details of conductivity solutions?

A. There are two kinds of EC solution for the four bottles. They are 1413 uS/cm and 12.88ms/cm.

For any questions/advice/cool ideas to share, please visit **DFRobot Forum** (http://www.dfrobot.com/forum/).

Documents

- Schematic (http://www.dfrobot.com/image/data/DFR0300/DFR0300_v1.0_schematic.pdf)
- Electrode User Manual (http://www.dfrobot.com/image/data/DFR0300/Conductivity%20Electrode%20User%20Manual.pdf)
-

Go Shopping > **Gravity: Analog Electrical Conductivity Sensor (https://www.dfrobot.com/product-1123.html)**

Category: **DFRobot (https://www.dfrobot.com/)** > **Sensors & Modules (https://www.dfrobot.com/category-156.html)** > **Sensors (https://www.dfrobot.com/category-36.html)** > **Liquid Sensors (https://www.dfrobot.com/category-68.html)**

Appendix J

Humidifier

Guardian Technologies LLC
26251 Bluestone Blvd. • Euclid, Ohio 44132
1.855.260.5566 • www.blackanddecker.com

BLACK+DECKER™

USE & CARE INSTRUCTIONS

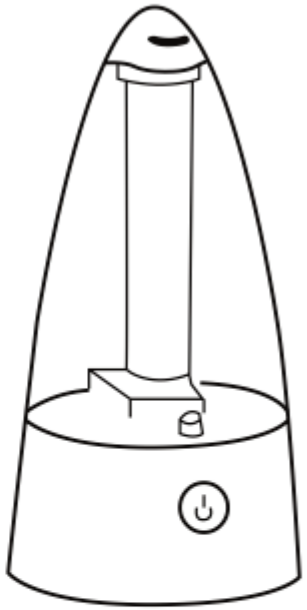


Table Top Ultrasonic Humidifier

Model No. BXHU090
1-Year Limited Warranty
www.blackanddecker.com
1.855.260.5566
REV0914

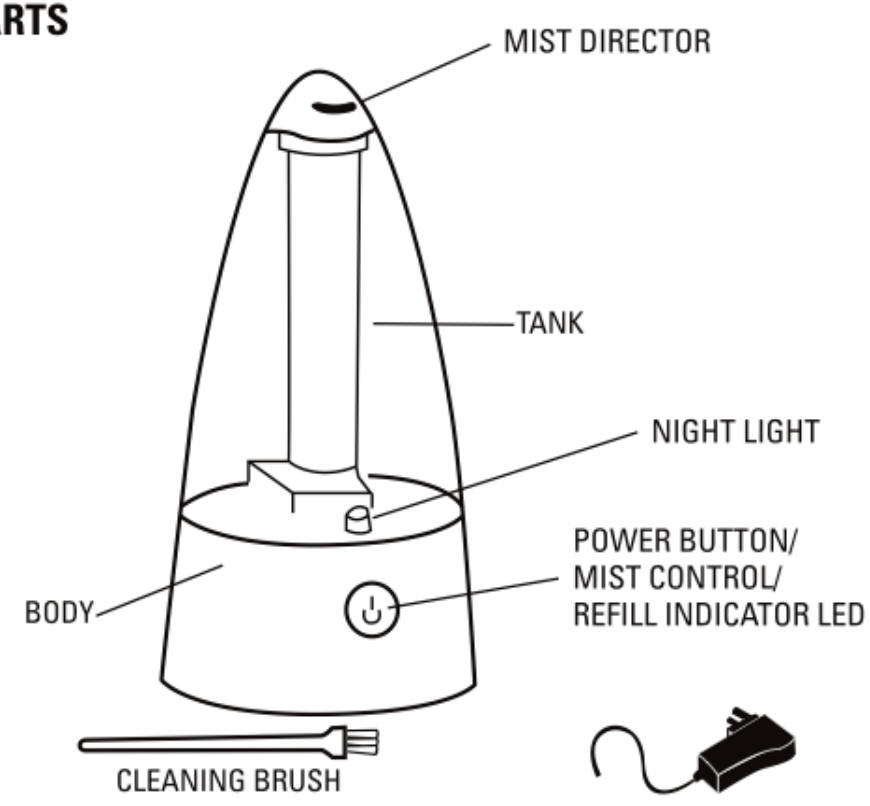
Date Purchased
month _____
year _____

PRODUCT SPECIFICATIONS AND PARTS

SPECIFICATIONS

Model Number: BXHU090
Humidifying Mode: Ultrasonic
Power Supply: AC24V 60Hz .5A
Power Consumption: 12W
Humidity Capacity: 80 ml/hr
Tank Capacity: 0.21 gallons
Dimensions: Width 5.5 inches - Height 11 inches - Depth 5.5 inches
Weight: 0.95 pounds (Not including packaging or adapter)

PARTS



READ AND SAVE THESE INSTRUCTIONS

FUNCTIONS AND FEATURES

2-Speed Mist Control

The mist control (Low or High) can be selected by pressing the power button according to the Mode Chart below.

MODE CHART

MODE	# of Power Button Pushes	Setting	Night Light
Mode 1	1	Low Speed	OFF
Mode 2	2	Low Speed	ON
Mode 3	3	High Speed	ON
Mode 4	4	High Speed	OFF

Water Shortage Indicator

When the unit is low on water, the Refill Indicator LED on the body will change from green to red, and the unit will shut off. Simply add more water to continue use.

Mist Director

The mist direction can be selected through 360° by turning the spout.

Cleaning Brush

The ultrasonic disk cleaning brush is a small brush which comes in the carton with the humidifier.

Night Light

Night light can be turned on and off with the power button on the front of the humidifier. *See MODE CHART above.

Humidifier Tank

When the humidifier water tank is removed from the body of the unit the power automatically shuts off.

READ AND SAVE THESE INSTRUCTIONS

WARNINGS

Failure to comply with the warnings listed above may result in electric shock or serious injury.

This product should be used only in accordance with the specifications outlined in this manual. Usage other than what has been specified here may result in serious injury.

- Disassembly, repair or remodeling by an unauthorized person may result in serious harm.
- Do not use if adapter plug is damaged or loose.
- Keep this product out of the reach of children and away from pets.
- Be careful not to put water in the humidity spout.
- Before filling or cleaning the unit, make sure it is unplugged.
- Once the humidifier has been turned on, do not move it and do not disassemble the water tank.
- Do not move when in operation.
- Do not remove the water tank from the unit while it is on.
- Do not handle the adapter plug with wet hands.
- Do not excessively bend, twist or pull the adapter cable.
- Avoid placing this product where the humidity is pointed directly at an object.
- Do not directly inhale the humidity.
- Do not place this product on a sloped or unstable surface.
- When not in use, unplug the unit.
- Do not fill the water tank with hot or boiling water.
- Do not use this product in direct sunlight, or near a gas stove or heater.
- If the water tank becomes cracked or damaged, do not use.
- Do not keep this product running for an extended period of time.
- Do not clean the unit or water tank with detergents or chemicals of any kind.
- Do not use this product near any other electronic device.
- Do not cover the humidity opening at any time during use.
- Do not use this product near a sink.
- Do not place this product on an absorbent surface.
- Do not pour anything but water into the water tank.
- Children cannot recognize the hazards associated with the usage of electrical appliances. For this reason, always supervise children when they are near the humidifier.
- If the mist comes in contact with the floor prior to evaporating, the floor surface may be damaged. We do not accept any liability for damage in the case of the unit being placed incorrectly.
- The use of water additives, such as ethereal/ essential oils, fragrances, eucalyptus, water conditioners, etc. will damage the appliance materials and as a consequence the whole unit. Any use of such additives will void the manufacturer's warranty.
- IMPORTANT: Neither humans nor animals can hear the high frequency vibrations.

Failure to comply with the warnings listed above may result in electric shock or serious injury.

READ AND SAVE THESE INSTRUCTIONS

WARNINGS

Failure to comply with the warnings listed above may result in electric shock or serious injury.

- Do not tilt or move the unit when unit is plugged into outlet.
- When unplugging from outlet hold humidifier securely.
- Do not put water in the spout.
- Do not damage the adapter cord.
- Do not place adapter cable over objects.
- Be careful not to get water in or on the power cord adapter or where it connects to the product.
- Do not touch water tank during operation.
- Do not submerse the unit in water or pour water on the unit.
- When emptying water from water tank, pour on drain side.
- Be careful not to put any detergent, any oils, any chemicals into water reservoir and/or tank.
- Do not place this product on cloth, carpet or vinyl. This may block air inlet.
- Unplug the adapter when unit is not in use for an extended period of time and/or when no one is present in the home.
- Do not drink the water from the tank.
- Do not cover the spout with a cloth or your hand and do not use without the spout.
- Do not keep water in the tank when not in use for an extended period of time.
- Do not put anything in the tank.
- Do not use the product near a gas oven range.
- Use clean or distilled water in the tank.
- Do not place anything on water tank or damage product by dropping.

WARNING: THE CORDS, WIRES AND/OR CABLES SUPPLIED WITH THIS PRODUCT CONTAIN CHEMICALS, INCLUDING LEAD OR LEAD COMPOUNDS, KNOWN TO THE STATE OF CALIFORNIA TO CAUSE CANCER AND BIRTH DEFECTS OR OTHER REPRODUCTIVE HARM. WASH HANDS AFTER USING.
(CALIFORNIA CODE OF REGULATIONS PROPOSITION 65)

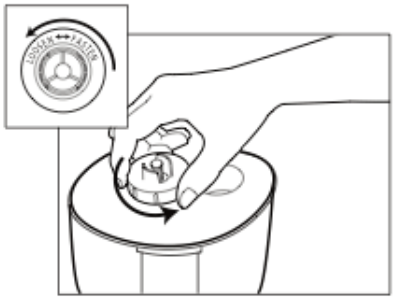
READ AND SAVE THESE INSTRUCTIONS

DIRECTIONS FOR USE - OPERATING INSTRUCTIONS

Make sure the unit is unplugged.

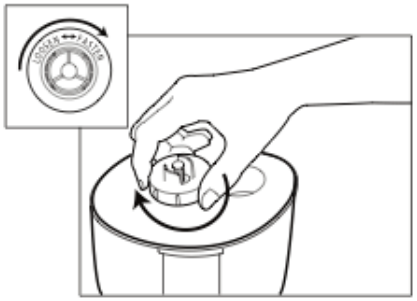
1. Separate the tank from the body of the unit.

2. Open the tank lid, turning it to the left.

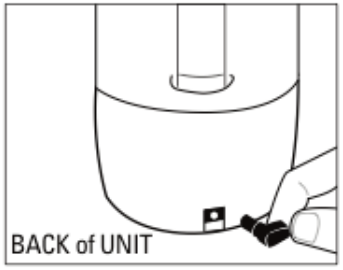


3. Pour cool, clean water directly into the tank. Do not pour anything but water into the tank.

4. Close the tank lid, turning it to the right. Then, re-attach the tank to the body of the unit.



5. Plug power adapter into back of humidifier unit. Plug into outlet.



6. Press the button to turn on. *See Mode Chart for further operating instructions.

NOTE: If you live in a hard-water area, we recommend the use of distilled water for your humidifier. This will help reduce the precipitation of mierals or 'white dust.'

READ AND SAVE THESE INSTRUCTIONS

MAINTENANCE - OPERATING INSTRUCTIONS

- Always unplug the unit before servicing it in any way.
- Do not submerse the unit in water, or allow water to enter the inside of the unit.

INSIDE THE BODY OF THE UNIT

Pour excess water out of the unit. Wash out the unit with fresh water, using the cleaning brush and a soft cloth as needed.

OUTER SURFACE OF THE UNIT

Wipe the surface of the unit with a soft damp cloth if needed.

WATER TANK

Fill water tank with clean water and shake to remove water scaling.

ULTRASONIC DISK

Remove the water tank and use the enclosed cleaning brush and 1 teaspoon of water and vinegar solution, every 1-2 weeks to remove build- up and deposits from this area.

Do not use any detergents or soap as this may damage the ultrasonic disc. This may also disperse detergent or soap residue that could be harmful to your health.

Do not scrub with finger tips or any sharp objects as this may cause damage to the ultrasonic disc.

***Clean the disk with the enclosed cleaning brush only. No other cleaning tool should be used. Brush only. (Fig. 2)**

STORAGE

- Fully dry the inside and outside of the unit before storing it.
- DO NOT leave water in the unit.
- Store in a cool, dry place.

READ AND SAVE THESE INSTRUCTIONS

TROUBLESHOOTING GUIDE

PROBLEM	SOLUTION
Water vapor & humidity are not produced.	Power Plug: Unplug and then try again. Power Failure: When the power is returned, try again. Make sure the water is in the tank and the tank is correctly attached. Clean the ultrasonic disc and its periphery.
Air blows but water vapor is not produced.	Excessive Water: Remove excess water from the humidifier body. Detergent residue and/or oil ingredients from cosmetics, etc may be in tank; wash out tank and try again. Clean the ultrasonic disk and its periphery. If you use hard water, replace with softer water.
Humidity level is low.	The surface of the ultrasonic disc is dirty: Clean the ultrasonic disc and its periphery. The water in the unit is too cold: Replace with cool, but not cold water.
The humidity has a bad smell.	Boil clean water and let cool. Use water after 24 hours. Poor maintenance or dirty water: Clean product thoroughly and fill with fresh water.
White dust forming on nearby furniture.	Hard water deposits a certain amount of dust. Use distilled water if this becomes a nuisance.
Night light is off.	See Mode Chart. (page E-3)
Power Button is red.	Water tank needs to be refilled with water.
Tank won't align properly back onto base of unit.	Tank only fits on base in one direction. Try turning the tank around until it fits securely in place on base.
Red/pink film or residue build-up on or around ultrasonic disk.	See cleaning instructions within manual. Clean humidifier more frequently.

LIMITED WARRANTY

To the consumer, Guardian Technologies LLC warrants this product to be free of defects in materials or workmanship commencing upon the date of the original purchase. Save your original sales receipt to validate start of warranty period. Warranty is not valid without receipt.

If this product should become defective within the warranty period, we will repair or replace any defective parts free of charge. All warranty repairs must be completed by Guardian Technologies LLC. This warranty **does not cover unauthorized repairs.** The warranty does not include unusual wear, damage resulting from accident, or unreasonable use of the product. This warranty only covers the product when used with genuine Guardian Technologies accessories. This warranty covers product that was purchased from authorized distributors. This warranty gives you specific legal rights and you may also have other rights (other rights may vary from state to state in the U.S.A.)

The product warranty registration can be completed online at www.blackanddecker.com. We consider the registration process important to ensuring superior service to our customers, however submitting the warranty registration is optional and does not affect your rights to utilize this warranty according to the conditions stated above. To submit product under warranty the complete machine must be delivered pre-paid to Guardian Technologies LLC. Please include complete information including: the problem, the model number of the product, the day of purchase, and a copy of the original sales receipt along with your name, address, and telephone (email optional). Address returns to the attention of: Customer Service, at the address below. Additional questions or comments can be made toll free to the number listed below.

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26251 Bluestone Blvd.
Euclid, Ohio 44132
1.855.260.5566
www.guardiantechnologies.com

This product has been tested and complies with the requirements for Federal Communications Commission, Part 18 for Radio/TV/Communication interference. Although tested, it may affect these devices. If the humidifier is found to interfere, separate the device and/or the humidifier. Conduct only the user maintenance found in this manual. Other maintenance and servicing can cause harmful interference and can void the required FCC compliance.

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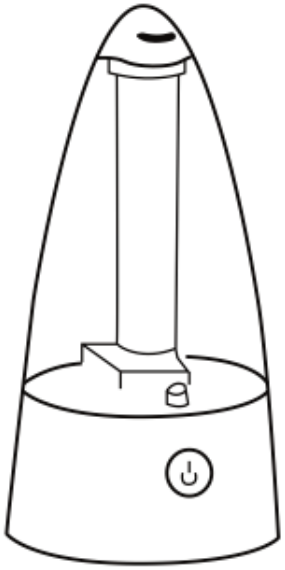
UTILISATION ET INSTRUCTIONS D'ENTRETIEN



Humidificateur ultrasonique pour table

Modèle nº BXHU090
Garantie limitée de 1 ans
www.blackanddecker.com
1.855.260.5566
REV0914

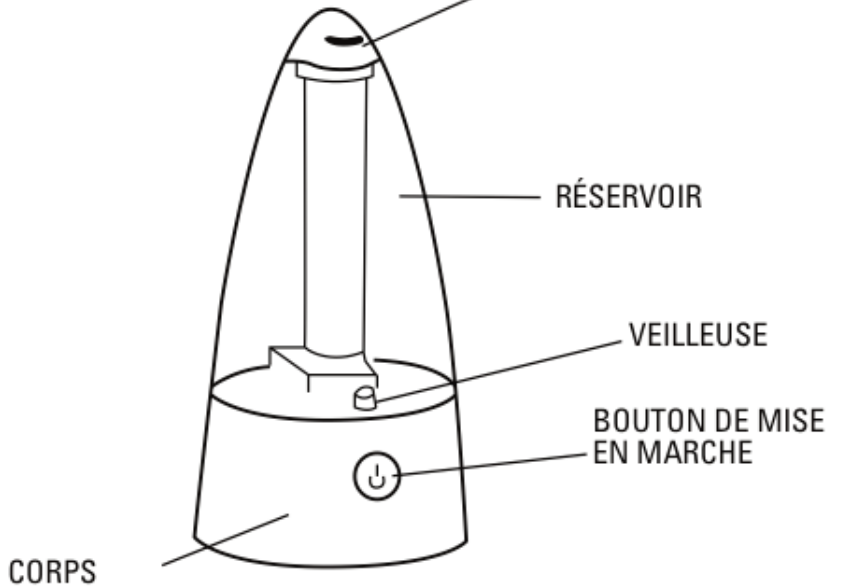
Date d'achat
mois _____
annee _____

LIRE ET CONSERVER CES INSTRUCTIONS
SPÉCIFICATIONS DU PRODUIT ET PIÈCES

SPÉCIFICATIONS

Numéro de modèle: BXHU090
Mode d'humidification: ultrasonique
Alimentation électrique: AC24V 60Hz .5A
Consommation électrique: 12W
Capacité d'humidification: environ 80 mL/hr
Capacité du réservoir: 5, 3 l (0,23 gallon)
Dimensions: largeur: 5,5 po; hauteur: 11 po; profondeur 5,5 po
Poids: 0,95 lb (emballage et adaptateur non compris)

PIÈCES



BROSSE À NETTOYER

*La brosse de nettoyage est emballée séparément de l'appareil dans le carton.

ADAPTATEUR

*L'adaptateur est emballé séparément de l'appareil dans le carton

FONCTIONS ET CARACTÉRISTIQUES

Réglage de la vaporisation - 2 vitesses

La vitesse de vaporisation (basee ou élevée) peut être sélectionnée en appuyant sur le bouton de mise en marche selon le tableau des modes ci-dessous.

MODE	Appuyez sur le bouton de mise en marche X fois	Réglage	Veilleuse
Mode 1	1	Basse	ARRÊT
Mode 2	2	Basse	MARCHE
Mode 3	3	Élevée	MARCHE
Mode 4	4	Élevée	ARRÊT

Indicateur de manque d'eau

Lorsque le niveau d'eau du réservoir atteint un minimum, le voyant DEL de remlissage situé sur le corps de l'appareil passe du vert au rouge et l'unité s'éteint. Ajoutez simplement de l'eau et remettez en marche l'unité.

Orientation de la brumisation

La brumisation peut s'effectuer sur 360^0 en tournant l'orifice d'échappement.

Brosse de nettoyage

La brosse de nettoyage du disque ultrasonique est une petite brosse fournie dans le carton de l'humidificateur.

Veilleuse

La veilleuse peut être allumée ou éteinte à l'aide du bouton de mise en marche à l'avant de l'humidificateur.

Réservoir de l'humidificateur

Lorsque le réservoir est déconnecté de l'humidificateur, l'appareil s'éteint automatiquement.

AVERTISSEMENTS

Le non-respect des avertissements mentionnés ci-dessus peut causer une électrocution ou des blessures graves

Ce produit doit être utilisé en conformité avec les directives indiquées dans le présent guide. De graves blessures peuvent résulter d'un usage du produit autre que celui indiqué dans leprésent guide.

- De graves blessures peuvent résulter du démontage ou du reconditionnement de l'unité ou des réparations apportées à celle-ci par une personne non autorisée.
- N'utilisez pas l'unité si la prise de l'adaptateur est endommagée ou desserrée.
- Gardez l'unité hors de portée des enfants et des animaux de compagnie.
- Veillez à ne pas verser d'eau dans le bec de sortie de l'humidité.
- Veillez à débrancher l'unité avant de la nettoyer ou de remplir le réservoir d'eau.
- Lors que l'humidificateur est en marche ne le déplacez jamais et ne démontez jamais son réservoir.
- Ne déplacez pas l'humidificateur lors qu'il est en marche.
- Ne retirez pas le réservoir lorsque l'unité est en marche.
- Évitez de trop plier, tordre ou tirer le cordon de l'adaptateur.
- Évitez de placer l'unité dans un endroit où l'humidité est dirigée directement vers un objet.
- Ne touchez pas la prise de l'adaptateur avec les mains mouillées.
- Ne respirez pas directement l'humidité produite.
- Ne placez pas l'unité sur une surface inclinée ou instable.
- Debranchez l'unité lorsqu'elle n'est pas utilisée.
- Ne remplissez pas le réservoir d'eau chaude ou bouillante.
- N'utilisez pas l'unité à la lumière directe du soleil ou à proximité d'une cuisinière ou d'un calorifère à gaz.
- N'utilisez pas l'unité si le réservoir est fissuré ou endommagé.
- Ne laissez pas l'unité fonctionner durant des périodes prolongées.
- Ne nettoyez jamais l'unité ou le réservoir avec des détergents ou des produits chimiques.
- N'utilisez pas l'unité à proximité d'un autre appareil électronique.
- Ne recouvrez jamais le bec de sortie de l'humidité durant l'utilisation de l'unité.
- N'utilisez pas l'unité près d'un évier.
- Ne placez pas l'unité sure une surface abosrbante.
- Versez uniquement de l'eau dans le réservoir d'eau.

Le non-respect des avertissements mentionnés ci-dessus peut causer une électrocution ou des blessures graves.

LIRE ET CONSERVER CES INSTRUCTIONS

AVERTISSEMENTS

Le non-respect des avertissements mentionnes ci-dessus peut causer une electrocution ou des blessures graves.

- N'inclinez pas et ne déplacez pas l'unité lorsqu-elle est branchée.
- Tenez fermement l'unité lorsque vous la débranchez.
- Ne versez pas d'eau dans l'orifice de d'échappement.
- Veillez à ne pas abimer le cordon de l'adaptateur.
- Ne posez le câble de l'adaptateur sur des objets.
- Veillez à ne pas verser d'eau sur le cordon de l'adaptateur ou sur sa prise de branchement au produit.
- Ne touchez pas l'eau du réservoir pendant le fonctionnement de l'unité.
- Ne versez pas d'eau sur l'unité et ne l'immergez pas dans l'eau.
- Videz toujours l'eau du réservoir du côté de l'orifice d'évacuation.
- Veillez à ne pas verser de détergent, d'huile ou de produits chimiques dans l'eau et/ou dans le réservoir.
- Ne placez pas ce produit sur du tissu, une moquette ou du vinyle. Cela pourrait obstruer l'entrée d'air.
- Débranchez toujours l'adaptateur lorsque vous n'utilisez pas l'unité pendant une période prolongée et/ou lorsque vous vous absentez.
- Ne buvez pas l'eau du réservoir.
- Ne bouchez pas l'orifice d'échappement avec unchiffon ou votre main, et n'utilisez jamais l'unité sans l'orifice d'échappement.
- Ne placez aucun objet dans le réservoir.
- N'utilisez pas le produit à proximité d'une cuisinière à gaz.
- Utilisez toujours de l'eau propre ou distillée dans le réservoir.
- Pour ne pas endommager le produit, veillez à ne poser aucun objet sur le réservoir et à ne pas le laisser tomber.
- Ne laissez pas d'eau dans le'réservoir lorsque vous n'utilisez pas l'unité pendant une période prolongée.

ADVERTISSEMENT: LES CORDONS, FILS ÉLECTRIQUES ET/OU CÂBLES FOURNIS AVEC CET APPAREIL CONTIENNENT DES PRODUITS CHIMIQUES Y COMPRIS DU PLOMB OU DES COMPOSÉS DU PLOMB RECONNUS PAR L'ÉTAT DE CALIFORNIE COMME POUVANT CAUSER LE CANCER, DES MALFORMATIONS CONGÉNITALES ET D'AUTRES PROBLÈMES DE SANTÉ GÉNÉSIQUE. LAVEZ-VOUS LES MAINS APRÈS L'UTILISATION DE L'APPAREIL.

(CALIFORNIA CODE OF REGULATIONS PROPOSITION 65)

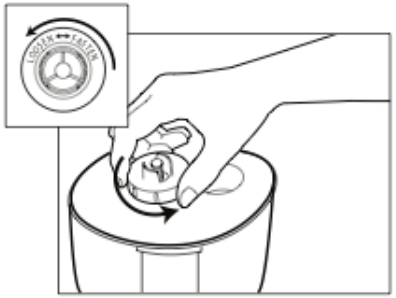
LIRE ET CONSERVER CES INSTRUCTIONS

MODE D'EMPLOI - FUNCTIONNEMENT

Vérifiez que l'unité est débranchée.

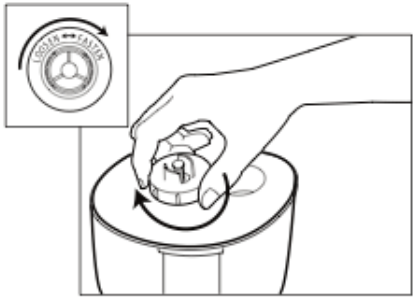
1. Dégagez le réservoir du corps de 'unité.

2. Ouvrez le bouchon du réservoir en le tournant vers la gauche.

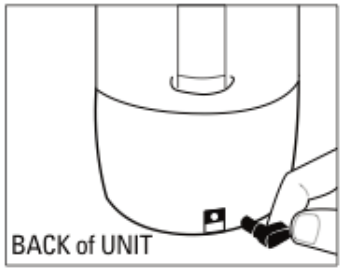


3. Versez de l'eau propre et fraîche directement dans le réservoir. Versez uniquement de l'eau dans le réservoir d'eau.

4. Fermez le bouchon du réservoir en le tournant vers la droite. Puis, rassemblez le réservoir au corps de l'appareil.



5. Branchez l'adaptateur à l'arrière de l'humidificateur. Et branchez-le à la prise de courant.



6. Appuyez sur le bouton de mise en marche. *Consultez le tableau des modes pour de plus amples instructions d'utilisation.

REMARQUE : Si vous vous trouvez dans une zone où l'eau est dure, nous recommandons d'utiliser de l'eau distillée dans votre humidificateur. Cela aide à réduire le dépôt de minéraux ou de « poussière blanche ».

ENTRETIEN - FUNCTIONNEMENT

- Débranchez toujours l'unité avant d'effectuer des travaux d'entretien.
- N'immergez pas l'unité dans l'eau et ne laissez pas d'eau pénétrer dans l'unité.

SURFACE INTÉRIEURE DU CORPS DE L'UNITÉ

Retirez le surplus d'eau de l'unité. Lavez l'unité à l'eau claire, à l'aide d'une brosse à nettoyer et d'un chiffon doux, si besoin est.

SURFACE EXTÉRIEURE DE L'UNITÉ

Le cas échéant, essuyez la surface de l'unité avec un chiffon doux et humide.

RÉSERVOIR D'EAU

Remplissez le réservoir avec de l'eau propre et remuez-le pour enlever les dépôts de tartre.

DISQUE ULTRASONIQUE

Retirez le réservoir et utilisez la brosse de nettoyage fournie et une solution de 1 cuillère à thé d'eau et de vinaigre toutes les 1 à 2 semaines pour éliminer les dépôts qui s'accumulent sur cette partie de l'appareil.

N'utilisez ni détergent ni savon. Leurs résidus pourraient endommager le disque ultrasonique, être dispersés pendant la brumisation et causer des blessures.

Cela peut aussi éliminer tout résidu de détergent ou de savon qui peut être nuisible à votre santé.

Si une pellicule rouge s'accumule sur le disque ultrasonique, nettoyez-le soigneusement avec un chiffon d'eau imbibée de 1 ou 2 gouttes de vinaigre blanc. Rincez ensuite le disque avec de l'eau propre.

ENTREPOSAGE

- Sechez entièrement l'intérieur et l'extérieur de l'unité avant de 'entreposer.
- Ne laissez PAS d'eau dans l'unité.
- Entreposez l'appareil dans un endroit sec et frais.

GUIDE DE DÉPANNAGE

PROBLEME	SOLUTION
Aucune vapeur d'eau et aucune humidité n'est produite.	Prise d'alimentation: débranchez, rebranchez et réessayez. Panne de courant: réessayez une fois la panne terminée. Vérifiez que le réservoir est rempli d'eau et qu'il est correctement installé. Nettoyez le disque ultrasonique et son pourtour.
L'air circule mais aucune vapeur d'eau n'est produite.	Surplus d'eau: Retirez tout surplus d'eau de l'humidificateur. Il se peut que du résidu de détergent et/ou d'huile issue de cosmétiques se soit déposé dans le réservoir: nettoyez le réservoir et réessayez. Nettoyez le disque ultrasonique et son pourtour. Si vous utilisez de l'eau dure, remplacez-la par de l'eau douce.
Le taux d'humidité est bas.	La surface du disque ultrasonique est sale: nettoyez le disque ultrasonique et son pourtour. L'eau dans l'unité est trop froide: remplacez l'eau froide par de l'eau fraîche.
L'humidité produite a une mauvaise odeur.	Faites bouillir l'eau et laissez-la refroidir. Attendez 24 heures avant d'utiliser l'eau. Piètre entretien ou eau croupie: nettoyez à fond le produit et remplissez-le d'eau fraîche.
Une poussière blanche se dépose sur les meubles à proximité de l'appareil.	L'utilisation d'une eau dure peut occasionner le dépôt d'une certaine quantité de poussière. Si ce phénomène devient gênant, utilisez une eau distillée.
La veilleuse st eteinte.	Consultez le tableau des modes. (page F-3)
Le bouton de mise en marche est rouge.	Le reservoir d'eau doit etre rempli.
Le reservoir ne s'aligne pas correctement sur la base de l'appareil.	Le réservoir ne s'emboîte sur la base de l'appareil que dans une direction. Faites pivoter le réservoir jusqu'à ce qu'il s'emboîte correctement sur la base.
Pellicule rouge/rose ou résidus sur ou autour du disque ultrasonique.	Consultez les instructions de nettoyage indisuqées dans le manuel. Nettoyez l'humidificateur plus souvent.

GARANTIE LIMITÉE

Guardian Technologies LLC garantit au consommateur que cet appareil est exempt de défauts matériels ou de fabrication, à partir de la date d'achat originale. Veuillez garder votre reçu de vente original pour justifier la date d'entrée en vigueur de la période de garantie. Sans reçu, la garantie devient nulle et non avenue.

Si cet appareil s'avère défectueux pendant la période de garantie, nous réparerons ou remplacerons toutes les pièces défectueuses gratuitement. Toute réparation couverte par la présente garantie doit être effectuée par Guardian Technologies LLC. La présente garantie **ne couvre pas les réparations non autorisées**. La présente garantie ne couvre pas l'usure inhabituelle et les dommages causés par accident ou par une utilisation déraisonnable de l'appareil. La présente garantie ne couvre l'appareil que s'il est utilisé conjointement à des accessoires d'origine de Guardian Technologies. La garantie couvre uniquement un appareil acheté auprès de distributeurs agréés. La présente garantie vous donne certains droits juridiques. Vous pouvez également bénéficier d'autres droits (les droits peuvent varier d'un État à l'autre aux États-Unis).

L'enregistrement de garantie de l'appareil peut se faire en ligne à l'adresse www.blackanddecker.com. Nous considérons le processus d'enregistrement comme important afin d'assurer un service supérieur à notre clientèle. Cependant, l'envoi de cette carte de garantie est facultatif et n'affectera en rien vos droits de faire valoir cette garantie en accord avec les conditions susmentionnées. Pour faire valoir la présente garantie, l'appareil complet doit être envoyé en port payé à Guardian Technologies LLC. Veuillez fournir des informations exhaustives, notamment : spécifiez la nature du problème, le numéro de modèle, la date d'achat, et incluez vos nom, adresse et numéro de téléphone (courriel facultatif) ainsi qu'une copie du reçu de vente original. Retournez l'appareil à l'attention de : Customer Service, et à l'adresse indiquée ci-après. Posez vos questions ou faites part de vos commentaires au numéro sans frais indiqué ci-après.

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Cet appareil a été testé et déclaré conforme aux exigences requises selon la section 18 sur les interférences liées à la radio, à la télévision et autres appareils de communication de la Federal Communications Commission (FCC - Commission fédérale des communications). Bien que testé, cet appareil pourrait créer des interférences sur ceux susmentionnés. Si l'humidificateur provoque des interférences, écartez l'appareil et/ou l'humidificateur. Effectuez l'entretien uniquement suivant les indications fournies dans le présent manuel. Toute autre opération d'entretien ou de maintenance pourrait provoquer des interférences préjudiciables et annuler la conformité requise aux exigences de la FCC.

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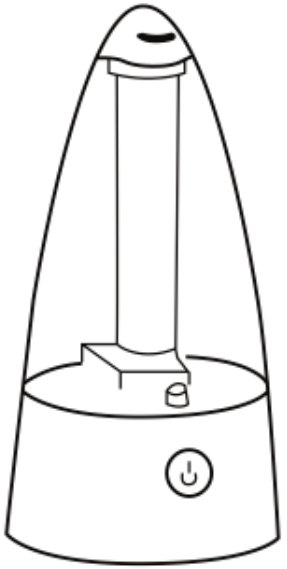
BLACK+DECKER™

INSTRUCCIONES DE USO Y CUIDADO



Humidificador Ultrasónico para Mesa

Modelo No. BXHU090
Garantía limitada por 1 años
www.blackanddecker.com
1.855.260.5566
REV0914

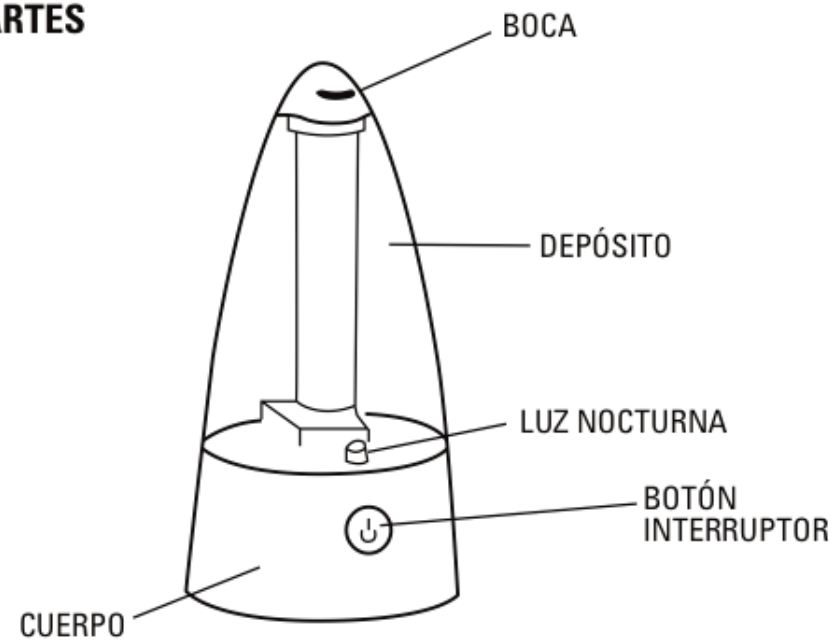
Fecha de compr
mes _____
año _____

ESPECIFICACIONES Y PARTES DEL PRODUCTO

ESPECIFICACIONES

Número de Modelo: BXHU090
Modo de humidificación: Ultrasónico
Suministro eléctrico: 120 VCA, 60 Hz (Adaptador de 120 VCA / 24 VCA)
Consumo de electricidad: 18W
Capacidad del depósito: 870 mililitros (0.23 galones)
Dimensiones: Ancho - 20.06 cm (7.9 pulg.); Altura - 21.59 cm (8.5 pulg.);
Profundidad - 8.89 cm (3.5 pulg.)
Peso: 599 gramos (1.32 libras) (Sin incluir el empaque y el adaptador)

PARTES



CEPILLO PARA LIMPIEZA
*El cepillo viene empacado en la caja por separado de la unidad principal.

ADAPTADOR DE CORRIENTE
*El adaptador viene empacado en la caja por separado de la unidad principal.

FUNCIONES Y CONFIGURACIONES

Control de neblina de 2 velocidades

El control de la neblina (baja o alta) puede seleccionarse oprimiendo el boton interrupteur segun la tabla de modo de funcionamiento a continuacion.

MODO	Veces que hay que oprimir el boton	Ajuste	Luz Nocturna
Mode 1	1	Baja	APAGADO
Mode 2	2	Baja	ENCENDIDO
Mode 3	3	Alta	ENCENDIDO
Mode 4	4	Alta	APAGADO

Indicador de escasez de agua

Cuando la unidad tiene un nivel bajo de aqua, el indicador LED de relleno en el cuerpo del aparto cambiara de color verde a rojo y la unidad se apagara. Simplemente anada mas agua para continuar usando la unidad.

Regulador de dirección de la neblina

Puede elegir la dirección de salida de la neblina en cualquier punto en los 360º al girar la boca de humidificación.

Cepillo para limpieza

El cepillo para limpieza del disco ultrasónico es un cepillo pequeño que se incluye en la caja con el humidificador.

Luz Nocturna

La luz nocturna puede encenderse y apagarse con el botón interruptor que se encuentra en la parte delantera del humidificador.

Depósito del humidificador

Cuando se retira el depósito de agua del humidificador del cuerpo de la unidad, ésta se apaga automáticamente.

ANTES DE USAR ESTE PRODUCTO, LEA Y GUARDE ESTAS INSTRUCCIONES

ADVERTENCIAS

El no cumplir las advertencias enumeradas anteriormente puede provocar un choque eléctrico o lesiones severas.

Debe usarse este producto sólo de acuerdo a las especificaciones descritas en este manual. Usarlo de una manera diferente a lo indicado puede ocasionar lesiones severas.

- Desarmarlo, repararlo o remodelarlo por una persona no autorizada puede provocar daños severos.
- No lo utilice si el enchufe del adaptador está dañado o suelto.
- Mantenga este producto fuera del alcance de los niños y lejos de las mascotas.
- Tenga cuidado de no verter agua en la boca de humidificación.
- Antes de llenar o limpiar la unidad, asegúrese que esté desconectada.
- Una vez que haya encendido el humidificador, no lo mueva ni desarme la cubeta.
- No lo mueva cuando esté funcionando.
- No retire la cubeta si la unidad está encendida.
- No tome el enchufe del adaptador con las manos mojadas.
- No doble, tuerza ni jale excesivamente el cable del adaptador.
- Evite colocar este producto de manera que la neblina de humidificación apunte directamente a un objeto.
- No inhale la neblina de humedad directamente.
- No coloque este producto sobre una superficie inclinada o inestable.
- Cuando no la use, desconecte la unidad.
- No llene la cubeta con agua caliente o hirviendo.
- No use este producto bajo la luz solar directa ni cerca de una estufa o calentador de gas.
- No lo use si la cubeta se agrieta o presenta daños.
- Evite que este producto funcione por un período prolongado.
- No limpie la unidad ni la cubeta con detergentes ni productos químicos de ningún tipo.
- No use este producto cerca de cualquier dispositivo electrónico.
- Cuando lo use, no cubra la apertura de humidificación en ningún momento.
- No use este producto cerca de un lavabo o fregadero.
- No coloque este producto sobre una superficie absorbente.
- No vierta ningún otro líquido en el depósito que no sea agua limpia.

El no cumplir las advertencias enumeradas anteriormente puede provocar un choque eléctrico o lesiones severas.

ANTES DE USAR ESTE PRODUCTO, LEA Y GUARDE ESTAS INSTRUCCIONES

ADVERTENCIAS

El no cumplir las advertencias enumeradas anteriormente puede provocar un choque eléctrico o lesiones severas.

- No incline ni mueva la unidad mientras esté conectada en el tomacoriente.
- Cuando lo desconecte del tomacorriente sostenga el humidificador de manera segura.
- No vierta agua en la boca de humidificación.
- No dañe el cordón del adaptador.
- No coloque el cable del adaptador sobre ningún objeto.
- Tenga cuidado de no dejar penetrar agua al cordón del adaptador ni sobre él, ni donde se conecta al producto.
- No toque el depósito de agua mientras está funcionando la unidad.
- No sumerja la unidad en agua ni vierta agua sobre ella.
- Cuando vacíe el agua del depósito, viértala por el lado de drenaje.
- Tenga cuidado de no verter detergente, aceites ni otras sustancias químicas en el depósito de agua y/o tanque.
- No coloque este producto sobre telas, alfombras o vinilo. Podría bloquear la entrada de aire.
- Desconecte el adaptador cuando no use la unidad durante un período prolongado y/o cuando no se encuentre ninguna persona en la casa.
- No beba el agua del depósito.
- No cubra la boca de humidificación con tela ni con su mano, ni tampoco use el periodo prolongado.
- No coloque ningún objeto en el depósito.
- No use el producto cerca de un horno o estufa de gas.
- Use sólo agua limpia o destilada para llenar el depósito.
- No coloque ningún objeto sobre el depósito de agua ni dañe el producto dejándolo caer.

ADVERTENCIA: LOS CORDONES, ALAMBRES Y/O CABLES SUMINISTRADOS CON ESTE PRODUCTO CONTIENEN SUSTANCIAS QUÍMICAS QUE INCLUYEN PLOMO O COMPUESTOS DE PLOMO, CONSIDERADOS EN EL ESTADO DE CALIFORNIE COMO CAUSANTES DE CÁNCER, DEFECTOS DE NACIMIENTO U OTROS DAÑOS REPRODUCTIVOS. LÁVESE LAS MANOS DESPUÉS DE USARLO.

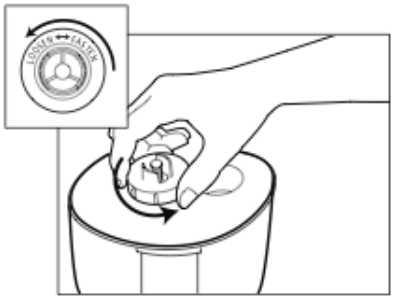
(CALIFORNIA CODE OF REGULATIONS PROPOSITION 65)

INSTRUCCIONES DE USO - FUNCIONAMIENTO

Asegúrese que la unidad esté desconectada.

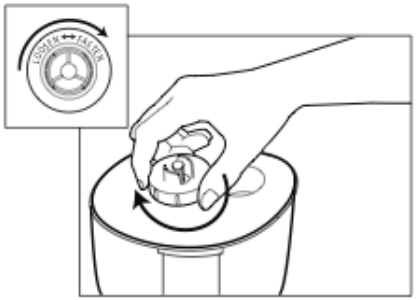
1. Retire el depósito del cuerpo de la unidad.

2. Abra la tapa del depósito girándola hacia la izquierda.

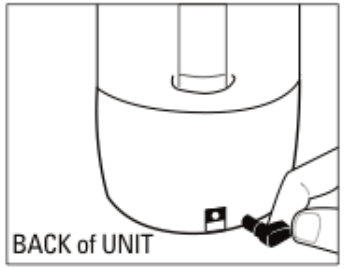


3. Vierta agua fría y limpia directamente en el depósito. No vierta ningún otro líquido en el depósito que no sea agua limpia.

4. Cierre la tapa del depósito girándola hacia la derecha. Luego, vuelva a colocar el depósito en el cuerpo de la unidad.



5. Conecte el adaptador de corriente en la parte trasera del humidificador. Conéctelo en un tomacorriente.



6. Oprima el botón interruptor para encenderlo. *Consulte las intrucciones adicionales en la tabla de modo de funcionamiento.

NOTA: Si vive en un área de agua dura, le recomendamos que utilice agua destilada en su humidificador. Esto ayudará a disminuir la precipitación de minerales del agua o “el polvo blanco”.

MANTENIMIENTO - FUNCIONAMIENTO

- Desconecte siempre la unidad antes de darle mantenimiento.
- No sumerja la unidad en agua ni permita que entre agua dentro de la unidad.

INTERIOR DEL CUERPO DE LA UNIDAD

Saque el exceso de agua de la unidad. De ser necesario, lave la unidad con agua fresca con un cepillo para limpieza y un paño suave.

SUPERFICIE EXTERIOR DE LA UNIDAD

De ser necesario, limpie la superficie de la unidad con un paño suave, húmedo.

DEPÓSITO DE AGUA

Llene el depósito con agua limpia y agite para eliminar el sarro.

DISCO ULTRASÓNICO

Retire el depósito de agua y use el cepillo para limpieza incluido junto con 1 cucharadita de solución de vinagre y agua, cada semana o dos semanas, para eliminar las incrustaciones y materiales depositados en esta área.

No use ningún detergente ni jabón ya que podría dañar el disco ultrasónico. Hacerlo podría dispersar residuos de detergente o jabón con la neblina provocando daños corporales.

Esto también puede dispersar los residuous de detergente o jabón que podrían ser perjudiciales para su salud.

Si observa acumulaciones de color rojo en el disco ultrasónico, limpie cuidadosamente con un paño suave con 1 ó 2 gotas de vinagre blanco. Enjuague con agua limpia.

ALMACENAMIENTO

- Antes de guardar la unidad seque completamente la superficie interior y el exterior.
- NO deje agua dentro de la unidad.
- Guárdela en un lugar fresco y seco.

ANTES DE USAR ESTE PRODUCTO, LEA Y GUARDE ESTAS INSTRUCCIONES

GUÍA DE SOLUCIÓN DE PROBLEMAS

PROBLEMA	SOLUCIÓN
La unidad no produce vapor de agua ni humedad.	Enchufe: Desconéctelo, vuelva a conectar e intente nuevamente. Interrupción del suministro eléctrico: Cuando se restablezca el servicio, intente nuevamente. Verifique que el agua esté dentro de la cubeta y que ésta esté conectada correctamente. Limpie el disco ultrasónico y toda la periferia.
Sale aire pero no se produce vapor.	Cantidad excesiva de agua: Quite el exceso de agua del cuerpo del humidificador. Pudiera haber residuos de detergente o ciertos aceites de cosméticos, etc. en el depósito: Lave bien el depósito e intente nuevamente. Limpie el disco ultrasónico y toda la periferia. Si usa agua dura, sustitúyala con agua blanda.
Nivel de humedad bajo.	La superficie del disco ultrasónico está sucia: Limpie el disco ultrasónico y toda la periferia. El agua de la unidad está demasiado fría: Reemplace con agua fresca, pero que no esté fría.
La humedad despide mal olor.	Hierva el agua limpia y déjela enfriar. Use el agua después de 24 horas. Mantenimiento deficiente o agua sucia: Limpie el producto meticulosamente y llénelo de agua fresca.
En los muebles cercanos a la unidad está apareciendo un polvo blanco.	El agua dura puede crear ciertos depósitos de polvo. Si le molesta este polvo, use agua destilada en lugar de agua del grifo.
La luz nocturna está apagada.	Consulte la tabla de modo de funcionamiento. (pagina S-3)
El botón interruptor emite luz roja.	Debe rellenar el depósito con agua.
El depósito no se alinea correctamente dentro de la base de la unidad.	El depósito solo entra en la base en una sola dirección. Intente darle vuelta al depósito hasta que encaje de manera segura en la base.
Película roja o rosa, o acumulación de residuous en o alrededor del disco ultrasónico.	Consulte las intrucciones de limpieza en el manual. Limpie el humidificador con mayor frecuencia.

GARANTÍA LIMITADA

Para el consumidor, Guardian Technologies LLC garantiza que este producto se encuentra libre de defectos de materiales o mano de obra a partir de la fecha de compra original. Guarde el recibo de compra original para validar el inicio del período de garantía. La garantía no es válida sin el recibo correspondiente.

Si durante el período de garantía se encuentra que el producto es defectuoso, repararemos o reemplazaremos las piezas defectuosas sin ningún costo. Todas las reparaciones cubiertas por la garantía deben ser realizadas por Guardian Technologies LLC. Esta garantía **no cubre las reparaciones no autorizadas.** La garantía no cubre los problemas ocasionados por desgaste inusual, daños que resulten por un accidente o el uso no razonable del producto. Esta garantía sólo cubre el producto si se utiliza con accesorios genuinos de Guardian Technologies. Esta garantía cubre el producto que se adquirió con un distribuidor autorizado. Esta garantía le otorga derechos legales específicos y usted pudiera tener otros derechos adicionales (los cuales varían en cada estado en los EE. UU.)

Puede completar el registro de la garantía en línea en www.blackanddecker.com. Consideramos que el proceso de registro es importante para garantizar el servicio superior a nuestros clientes; sin embargo, el envío del comprobante de registro es opcional y no afecta sus derechos para utilizar la garantía de acuerdo a las condiciones estipuladas anteriormente. Para enviar el producto cubierto por la garantía, el aparato completo debe enviarse con porte pagado por anticipado a Guardian Technologies LLC. Incluya toda la información, incluso: la descripción del problema, el número de modelo del producto, la fecha de compra, una copia del recibo de compra original junto con su nombre dirección y número de teléfono (puede incluir su dirección de correo electrónico de manera opcional.) Dirija las devoluciones a la atención de: Departamento de servicio al cliente, a la dirección que se indica a continuación. Si tiene preguntas o comentarios llame sin costo al número de teléfono que aparece abajo.

Guardian Technologies LLC
26251 Bluestone Blvd.
Euclid, Ohio 44132
1.855.260.5566
www.guardiantechnologies.com

Este producto ha sido sometido a pruebas y cumple con los requisitos de la Comisión Federal de Comunicaciones, o FCC, Parte 18, correspondiente a la interferencia de Radio/TV/Comunicaciones. Aunque ha sido probado, aun así puede afectar estos dispositivos. Si observa que el humidificador crea interferencia, ponga el dispositivo o el humidificador aparte. Realice únicamente el servicio de mantenimiento indicado en este manual. Otro tipo de mantenimiento y servicio puede provocar interferencia perjudicial y anular el cumplimiento requerido por la FCC.

Guardian Technologies LLC
26251 Bluestone Blvd. • Euclid, Ohio 44132
1.855.260.5566 • www.blackanddecker.com

Appendix K
ActiveAQUA Pump

ActiveAQUA™

TROUBLESHOOTING GUIDE

SYMPTOM	CAUSE	SOLUTION
The pump does not run	Power is not turned on	Turn on the power
	Incorrectly plugged in	Plug in correctly
	Bound impeller	Remove foreign matter from impeller
The motor repeats ON/OFF without running pump. It stops and does not restart	Wrong voltage	Correct voltage
	The water intake or outlet pipe is clogged with foreign matter	Clean out the intake and outlet
The pump runs with reduced or no performance	Wrong frequency	Correct frequency
	Impeller worn out	Replace impeller
	Low water level	Ensure the pump is fully submerged
The pump runs normally at the beginning but the water flows sluggishly or there is no water	Hose is too long or clogged	Shorten hose and/or clean out
	Air in the impeller chamber	To get rid of air, put pump into the water. Turn the switch to "ON" and "OFF" intermittently to clear air from pump

LIMITED WARRANTY

Your Active Aqua Pump is guaranteed to work for one year from the date of retail purchase. Replaceable filter material not included. Save your retail receipt/invoice, a copy is required for all warranty work.

Any alterations to a pump or cord will void warranty. Contact the place of purchase for repair or replacement. Active Aqua Pumps are sold and serviced only through dealers.

HYDROFARM®

ActiveAQUA™

ACTIVE AQUA SUBMERSIBLE PUMP

FOR MODELS: AAPW40, AAPW160, AAPW250, AAPW400, AAPW550, AAPW800, AAPW1000

Active Aqua Pumps from Hydrofarm are carefully inspected and tested to ensure both safety and operating performance. However, failure to follow the instructions and warnings in this manual may result in pump damage and/or serious injury. Be sure to read and save this manual for future reference.

HYDROFARM®

WARNING

- This pump is supplied with a grounding conductor and a grounding type attachment plug. To reduce risk of electric shock, connect only to a properly grounded outlet.
- Do not remove the grounding pin from the plug.
- Do not connect to any voltage other than that shown on the pump.
- Do not pump flammable liquids.
- The national electric code requires that a grounded fault circuit interrupter (GFCI) be used in the branch circuit supplying fountain pumps and other pond equipment. See your electrical supplies dealer for this device.
- Do not use with water above 86°F (30°C).
- Do not allow the pump to freeze in winter, remove pump from fountains and ponds and store in a frost-free area.

CAUTION:

Always disconnect from electrical outlet before handling the pump.

Do not let the pump run dry.

Do not lift the pump by the power cord.

Do not pump heated liquids.

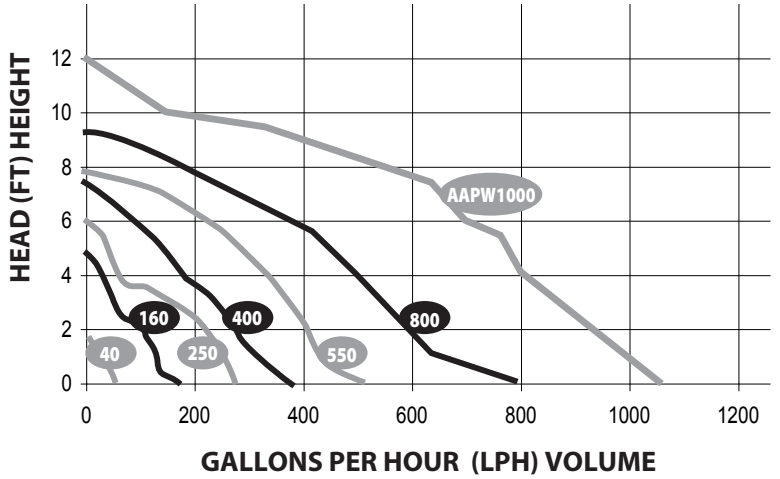
Do not operate in salt water.

PERFORMANCE

- A clogged or dirty intake screen will greatly reduce performance. If the pump is used on a dirty surface, raise it slightly to reduce the amount of debris contacting the intake. If less flow is desired, adjust the flow control knob on the front of the pump or restrict the discharge flow.
- This pump can be used submersed or in-line. Note that when used in-line it should be placed below the water level since it is not self priming. Never run this pump dry. If initially the pump does not work, it may be “air locked”. To clear the air lock, unplug the pump and rotate 180 degrees under water, repeat if necessary.

  The included gray fitting should be attached to the inlet side of the pump only when operated in-line. The barbed gray and black fittings use a different sized thread and rubber O-rings. The gray in-line fitting attaches to the front of the pump and uses the larger sized O-ring. The black fittings attach to the top of the pump and use the smaller sized O-ring. Please use only as intended (see chart for reference).

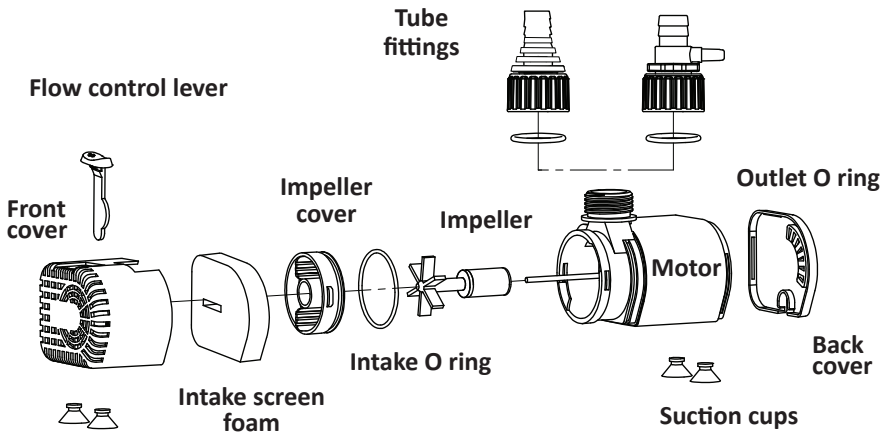
ACTIVE AQUA SUBMERSIBLE PUMP COMPARISON CHART



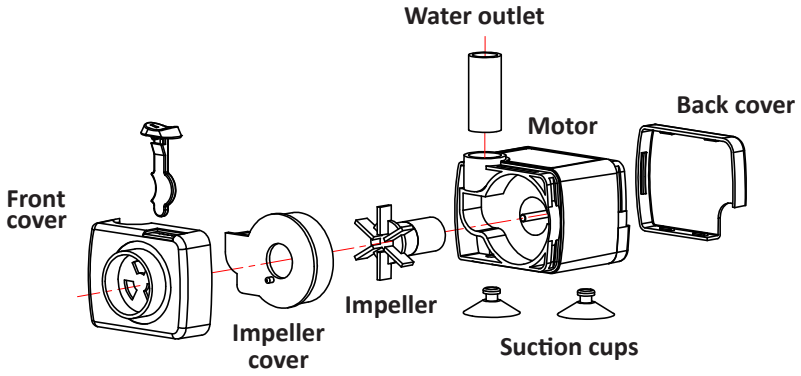
Product Item Code	Rated GPH	(LPH)	Recommended Size gallons	(litres,litros)	Watts	Fitting Sizes Included inches	(milimeters)
AAPW40	43	(163)	5	(19)	3	5/16"	(8mm)
AAPW160	172	(650)	15	(57)	9.5	1/2"	(12.7mm)
AAPW250	291	(1,100)	25	(95)	16	1/2", 3/4"	(12,7mm, 19mm)
AAPW400	370	(1,400)	40	(151)	24	1/2", 3/4"	(12.7mm, 19mm)
AAPW550	529	(2,000)	55	(208)	33	1/2", 3/4"	(12.7mm,19mm)
AAPW800	793	(3,000)	80	(303)	58	1/2", 3/4", 1"	(12.7mm,19mm, 25mm)
AAPW1000	1110	(4,200)	100+	(378+)	92	1/2", 3/4", 1"	(12.7mm,19mm, 25mm)

Intake fittings are not represented in this chart.
Each aeration kit contains an extra fitting.

AAPW160



AAPW40



MAINTENANCE

To clean the pump, remove the front cover and the impeller. Use a small brush and stream of water to remove any debris.

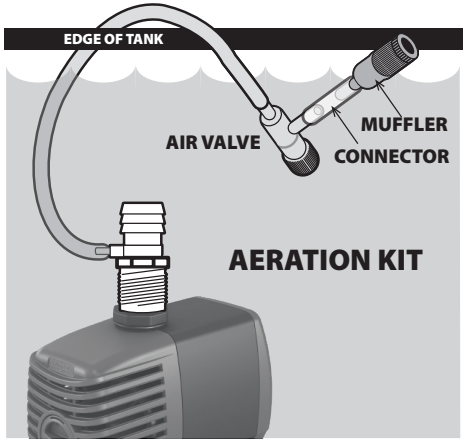
IF THE PUMP FAILS TO OPERATE, CHECK THE FOLLOWING:

- Check the circuit breaker and try another outlet to ensure the pump is getting electrical power. NOTE: Always disconnect from electrical outlet before handling the pump.
- Check the pump discharge and tubing for kinks and obstructions. Algae buildup can be flushed out with a garden hose.
- Check the inlet screen to ensure it is not clogged with debris.
- Remove the pump inlet to access the impeller area. Turn the rotor to ensure it is not broken or jammed.
- Monthly maintenance will add to your pump's life. NOTE: Ensure that the electrical cord loops below the electrical outlet to form a "Drip Loop." This will prevent water from running down the cord into the electrical outlet.

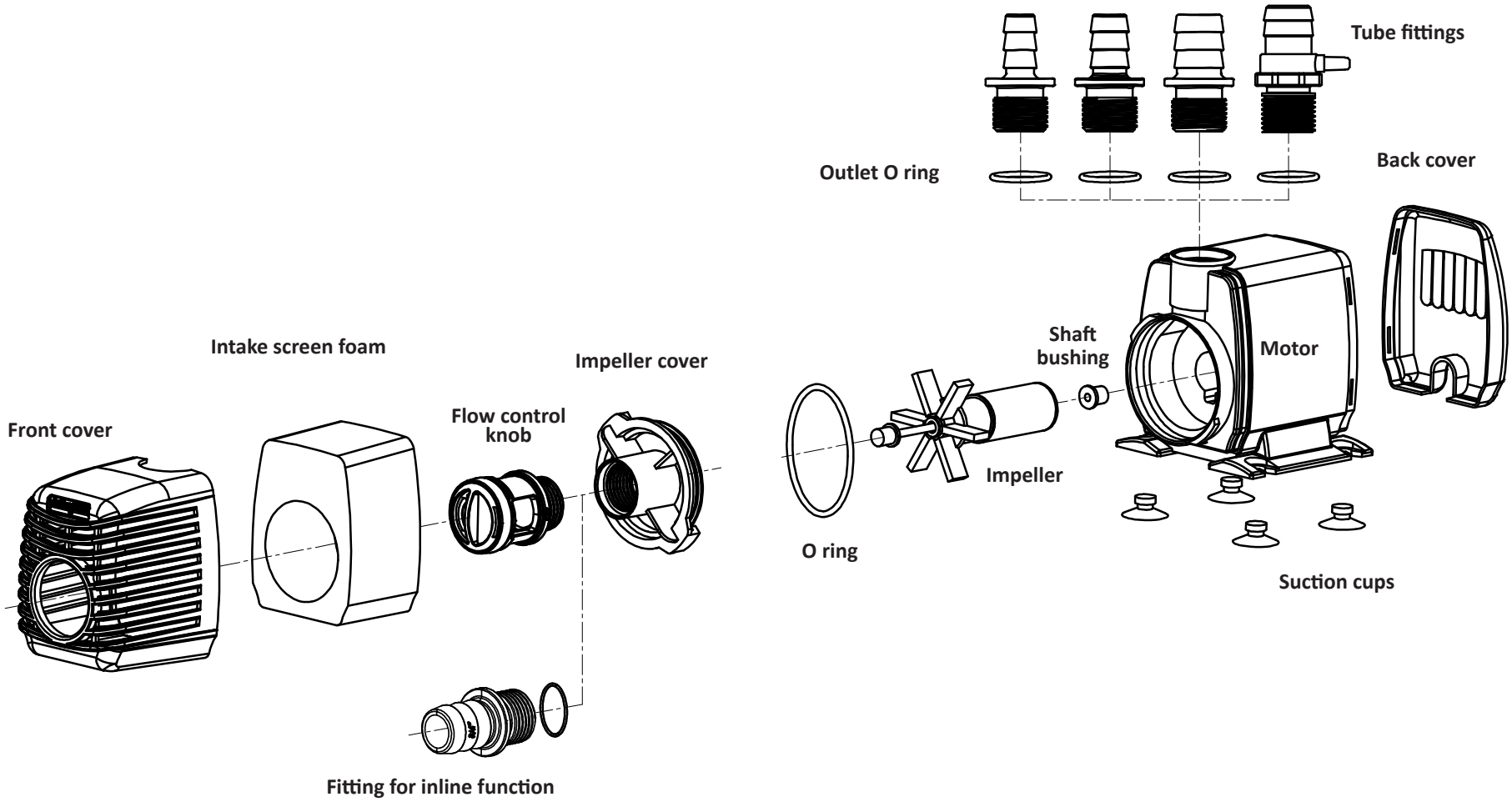
AERATION KIT

INTAKE INSTRUCTIONS: The Venturi intake provides air induction when the airline is connected to the small air intake port on the included hose fitting. Attach the air muffler to the air control valve using the tube connector.

Attach the air control assembly to the Venturi air port on the included hose fitting. Keep the air valve and muffler assembly above the water surface level. This pump can be used with or without the Venturi air intake.



AAPW250, AAPW400, AAPW550, AAPW800, AAPW1000



Appendix L

Emerald Harvest 3 Part Nutrient Series

PROFESSIONAL 3-PART NUTRIENT SERIES

EMERALD HARVEST®

			GROW	MICRO	BLOOM	EMERALD GODDESS®	KING KOLA®	HONEY CHOME®	ROOT WIZARD®
			Professional 3-Part Nutrient Series			Premium Plant Tonic	Powerful Bloom Booster	Aroma & Resin Enricher	Massive Root Builder
Vegetative Phase (18-hour light)		Seedlings & Cuttings	2.0 mL	2.0 mL	2.0 mL	-	-	-	-
		Transplants	4.0 mL	2.0 mL	1.0 mL	-	-	-	-
		Early Vegetative	6.0 mL	3.0 mL	2.0 mL	6.0 mL	-	4.0 mL	15.0 mL
		Late Vegetative	8.0 mL	4.0 mL	2.0 mL	6.0 mL	-	4.0 mL	-
Flowering Phase (12-hour light)	Week 1	Transition	4.0 mL	4.0 mL	4.0 mL	6.0 mL	4.0 mL	4.0 mL	-
	Week 2	Early Flowering	2.0 mL	4.0 mL	8.0 mL	8.0 mL	8.0 mL	8.0 mL	15.0 mL
	Week 3	Early Flowering	2.0 mL	4.0 mL	8.0 mL	8.0 mL	8.0 mL	8.0 mL	-
	Week 4	Mid Flowering	2.0 mL	5.0 mL	10.0 mL	10.0 mL	12.0 mL	8.0 mL	-
	Week 5	Mid Flowering	2.0 mL	5.0 mL	10.0 mL	10.0 mL	12.0 mL	8.0 mL	-
	Week 6	Late Flowering	-	6.0 mL	11.0 mL	10.0 mL	8.0 mL	8.0 mL	-
	Week 7	Late Flowering	-	6.0 mL	11.0 mL	10.0 mL	8.0 mL	8.0 mL	-
	Week 8	Ripening	-	4.0 mL	11.0 mL	5.0 mL	4.0 mL	6.0 mL	-
	Week 9	Flush	2.0 mL	2.0 mL	2.0 mL	-	-	6.0 mL	-

Amounts are milliliters per gallon of water.
Do not premix concentrated nutrients.
Fill the reservoir with water & then add nutrients.
Always mix **Micro** with fresh water first, then add **Grow** &/or **Bloom**.
Monitor plants for signs of stress when following a more aggressive feeding program.

To extend the vegetative phase, repeat one or more late vegetative week(s).
To extend the flowering phase, repeat one or more mid flowering week(s).
Ideal pH range after mixing nutrients is 5.8–6.3.
Ideal water temp is 60–72°F (16–22°C).

Additional Emerald Harvest Supplements

CAL-MAG	STURDY STALK™
Calcium-Magnesium Supplement	Potassium Silicate Supplement
Use 5 mL per gallon when needed from early vegetative through late flowering phase. Recommended for use on water days only.	

This feeding chart is suitable for all growing media in recirculating or drain-to-waste systems.

Quick Conversions

Teaspoons (tsp)	Milliliters (mL)	Tablespoons (tbsp)	Ounces (oz)
1/4 tsp	1.0 mL	-	-
1 tsp	5.0 mL	1/3 tbsp	-
1 1/2 tsp	7.5 mL	1/3 tbsp	-
3 tsp	15.0 mL	1 tbsp	1/2 oz
6 tsp	30.0 mL	2 tbsp	1 oz

Liters (L)	US quarts (qt)	US gallons (gal)
0.95 L	1 qt	-
1.89 L	2 qt	-
3.79 L	-	1 gal
22.71 L	-	6 gal

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